Operator's Manual
The Coherent INNOVA®
Sabre™ Ion Laser

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Should you experience any difficulties with your laser or need any technical information, contact our Technical Support Hotline at 800-367-7890. Telephone coverage is available Monday through Friday (except U.S. holidays). On these days, Technical Support Engineers are available to provide product assistance and information.

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Preface

This manual provides operating and maintenance instructions for the INNOVA Sabre Ion Laser. Please refer Chapter Three, Laser Safety, which describes laser safety features and precautions. If you are unfamiliar with ion lasers in general, refer to Chapter Ten, Theory of Operation.

Read this manual carefully before operating the laser for the first time. Give special attention to the material in Chapter Three, Laser Safety, which describes the safety features built into the INNOVA Sabre Ion Laser.

Use of controls or adjustments or performance of procedures other than those specified in this manual may result in hazardous radiation exposure.

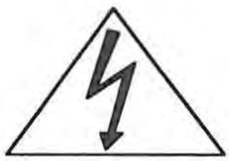
U.S. Export Control Laws Compliance

It is the policy of Coherent to comply strictly with U.S. export control laws.

Export and re-export of lasers manufactured by Coherent are subject to U.S. Export Administration Regulations, which are administered by the Commerce Department. In addition, shipments of certain components are regulated by the State Department under the International Traffic in Arms Regulations.

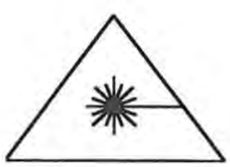
The applicable restrictions vary depending on the specific product involved and its destination. In some cases, U.S. law requires that U.S. Government approval be obtained prior to resale, export or re-export of certain articles. When there is uncertainty about the obligations imposed by U.S. law, clarification should be obtained from Coherent or an appropriate U.S. Government agency.

Symbols Used in This Manual



This symbol is intended to alert the operator to the presence of dangerous voltages within the product enclosure that may be of sufficient magnitude to constitute a risk of electric shock.

This symbol is intended to alert the operator to the presence of important operating and maintenance instructions.



This symbol is intended to alert the operator to the danger of exposure to hazardous visible and invisible laser radiation.

Operator's Manual

Chapter One
General Description

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Introduction

The INNOVA Sabre Ion Laser System consists of the laser head, power supply, remote control module, and the heat exchanger (Figure 1-1). Each system component including system features is described in the following paragraphs in this chapter. System specifications and parameters for various optical configurations are listed in Chapter Two.

System features include:

- Multiline, single line, and single-frequency operation, depending on the options selected.
- PowerTrack.
- Motorized rear plate for automatic wavelength selection and automatic rear plate alignment.
- TEM_{00} detector with automatic aperture selection.
- ν –Track/ ModeTune/ ModeTrack in single-frequency operation.
- Automatic external shutter.
- System diagnostics.
- CPU system control.

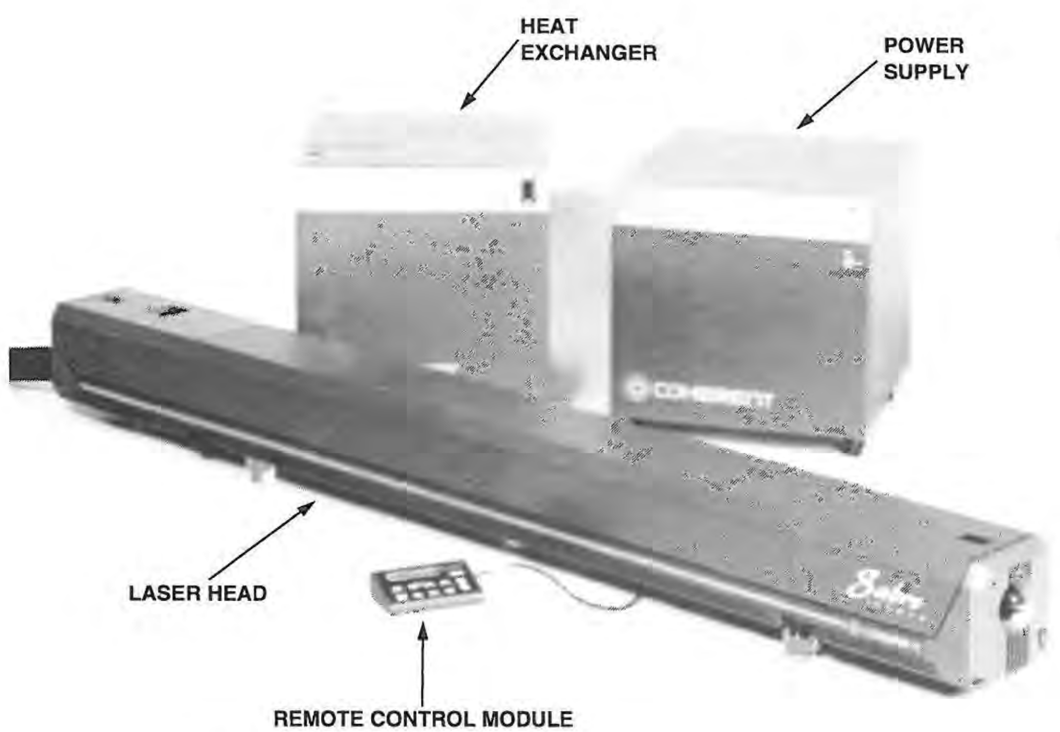

Figure 1-1. Sabre Ion Laser System

Laser Head

The active medium in the laser head is ionized argon or krypton gas contained in a low-pressure tube. The plasma tube is positioned inside an optical cavity consisting of two dielectrically coated laser mirrors.

Series V Laser Tube

The active medium in the laser head is a plasma of ionized gas contained in a low pressure tube. A DC current, passed through the gas inside the tube, provides the energy which is converted to laser light through the process of stimulated emission. Coherent manufactures a selection of mirrors for various applications (Tables A1 and A-2). As laser tube components are subject to a variety of extreme stresses during operation, the Series V plasma tube is fabricated from metal and ceramic components which are brazed together in a high temperature furnace. The tube is assembled in an ultraclean facility to prevent contamination of components which might impair laser operation. Metal-ceramic construction provides a rugged structure which assures high reliability and a long operating life.

Axial Field Magnet

To control the current density and internal gas recirculation, a magnetic field is used to confine the plasma discharge. This confinement is accomplished by the use of an electromagnet which forms a sheath around the tube. The magnet sheath also provides a channel for cooling water to flow directly across the single-piece ceramic tube, carrying away the extreme heat produced in the plasma.

Resonator Structure

All optical cavity components are attached to a rigid resonator structure consisting of three Super Invar rods. The Super Invar rods provide maximum power stability and cavity length stabilization. The resonator structure and laser tube/magnet assembly are kinematically isolated from the laser head enclosure and from each other.

Optical Configurations

The Sabre system can operate in different optical configurations. Each configuration described below requires its own set of optics. Changing configurations is described in Chapter Seven, Optics and Alignment Procedures.

Multiline Operation

In multiline operation, several wavelengths are produced at once, resulting in the maximum output power of the laser. This configuration can be used on any Sabre ion laser.

Single Line Operation

In single line operation, a wavelength selecting single line holder is inserted in the cavity to suppress all but one laser line. Argon Sabre uses three single line holders to cover the full wavelength range, individually optimized for the visible, UV, and deep/short UV wavelength regions. Krypton Sabre uses two single line holders individually optimized for the visible/IR and UV wavelength regions.

Single-Frequency Operation

A single laser line consists of numerous closely spaced frequency components. In single-frequency operation, all but one of these components are suppressed by use of an intracavity etalon. Three versions of the Sabre intracavity etalon are available (Refer to Chapter Eight, Single-Frequency Operation).

Due to the gimbal-mounted output coupler design of the Sabre, PowerTrack can operate in single-frequency configuration.

Intracavity Shutter

The function of the intracavity shutter is to stop laser output manually by blocking the optical cavity space between the two mirrors without switching off the power supply or the flow of current through the plasma tube. This is a safety feature which cannot be operated electrically.

Microprocessor Control

A CPU located in the head controls various functions of the Sabre. Two EEPROMs located in the laser head, store calibration constants for the plasma tube and laser head assembly. These constants are automatically downloaded to the main system CPU in the power supply whenever the system is started. Automatic calibration allows different heads and power supplies to be interchanged.

Photocell Detectors for Power and Mode

A beamsplitter assembly inside the head directs a fraction of the output light onto a photocell and a TEM_{00} detector. The current from the photocell is used by the system control circuitry as a measure of the laser output power. The signal from the TEM_{00} detector is used to determine whether or not the laser is operating in a single transverse mode and/or with a nearly Gaussian mode.

Safety Interlocks

The head cover is equipped with interlocks that prevent the laser from operating with the head sub-covers removed.

Means are provided to defeat this interlock for maintenance operations.

Laser Radiation Emission Indicator

The laser emission indicator lights 75 seconds prior to lasing and at all times when the tube is ionized.

Umbilical

The umbilical which connects the laser head and the power supply contains cooling water hoses as well as power and control cables. It is hard wired to the laser head and attaches to the power supply by one screw.

Front Bezel

The front bezel design allows a 1-32 inch threaded accessory to be conveniently mounted to the front of the laser head. Incorporated into the exit aperture of the front bezel is a Brewster window to minimize interactions between the external environment and the beam internal to the laser head.

Laser Head Automated Features

Motorized Rear Plate

Two stepper motors control the horizontal and vertical tilt of the rear plate on which the high reflector is mounted. This enables Sabre to search for lasing and peak for maximum power or to select a wavelength when operating in single line configuration. These operations can be selected from the remote module or a user supplied computer connected to the power supply.

After this is done, PowerTrack can be automatically or manually engaged to ensure that the alignment remains optimized.

Automatic Aperture

The Sabre automatic aperture is controlled using the remote control module. The intracavity aperture allows control of the output beam transverse mode structure by aperturing higher order modes to prevent lasing of these modes. Hence, a Gaussian transverse mode (TEM_{00}) is achieved. Typically, the output is adjusted for the largest aperture diameter that produces the highest output power with a TEM_{00} mode. The

aperture can also be fully opened for maximum output power in a beam that is typically non-Gaussian (multimode).

TEM_{00} detector

The TEM_{00} detector monitors the mode-beat noise created by the transverse modes and indicates when operating in TEM_{00} mode. The aperture assembly can be set to select the optimum aperture for TEM_{00} operation automatically.

PowerTrack™ Alignment Servo

Optimum cavity alignment of the Sabre is automatically maintained during operation through servo control of the output coupler (front mirror). This feature, called PowerTrack, permits long-term stable operation without the need to periodically optimize the mirror alignment. PowerTrack also enables the laser to produce full power within one minute after the system starts, eliminating most of the warm-up time normally required with ion lasers.

ν – Track

The cavity length of the Sabre laser can be adjusted to compensate for changes in ambient temperature. With ν-Track engaged, the absolute frequency of the system is locked to the extremely stable temperature dependent etalon transmission curve. This is accomplished by a coordinated motion of the four magnetic actuators which can translate the output coupler longitudinally. ν-Track should be used when operating the laser in single-frequency mode for best single-frequency stability and mode-hop free operation.

ModeTune

ModeTune is an automatic tuning routine that finds, and sets the etalon to the temperature that achieves the maximum output power during single-frequency operation.

ModeFineTune

ModeFineTune is a ModeTune subroutine that searches for and sets the etalon temperature to achieve the maximum output power. ModeFineTune searches over a narrower temperature range than ModeTune. While ModeFineTune is automatically used by ModeTune, it can also be accessed separately through the system software.

ModeTrack

ModeTrack is an active stabilization loop that continuously adjusts the etalon temperature to track the laser frequency and prevent mode hopping. As a result, power drift is kept at a minimum during single-frequency operation. This mode of

single-frequency operation can be used as an alternative to ν-Track.

External Shutter

The external water cooled shutter allows lasing but prevents radiation from exiting the head when closed. This shutter can be set to close automatically when certain integrated features are executed. The shutter can be controlled using the remote control module or by a user supplied computer connected to the power supply.

Power Supply

Electrical power to operate the plasma tube is drawn from an incoming 3-phase power line. The power supply conditions the power and uses a 3-wave rectifier and LC filter to provide DC current for the tube and magnet. A linear passbank regulates the current to minimize the optical noise on the output beam. The power supply also monitors safety interlocks and diagnoses system faults.

The power supply is controlled by a microprocessor (CPU) that communicates with the operator through a remote control module. Push-buttons on the remote control module allow control of operating parameters, and an LCD readout displays status and diagnostic information. The RS-232/422 interface or the optional IEEE-488 interface can be used to control the laser from a remote customer supplied computer.

Light Regulation

In Light Regulation Mode, the laser operator programs a desired laser output power through the remote control module. Circuitry in the power supply compares the desired power to the actual power by monitoring the signal from the photocell in the laser head. The circuitry continually adjusts the plasma tube current to maintain a constant laser output level.

Current Regulation

In Current Regulation Mode, the power supply maintains the plasma tube current at a constant value. This value can be adjusted from the remote control module; higher currents typically produce higher output power. While the minimum tube current on all models is 10 Amps, the maximum tube current depends on the model number. Refer to Chapter Two, System Specifications and Parameters, for maximum tube current.

RS-232/422 Interface

A standard RS-232/422 connector is located on the rear panel of the power supply. The RS-232/422 interface provides the operator with the option of remote computer control of the laser system. Any computer equipped with an RS-232/422 interface card can be used.

Optional IEEE-488 Interface

An IEEE-488 connector is located on the rear panel of the power supply. The optional IEEE-488 interface provides the operator with the option of remote computer control of the laser system. Any computer equipped with an IEEE-488 interface card can be used.

External Interlock Connector

Terminals on the rear of the power supply are provided for an external interlock connection. These terminals must be connected for the laser to operate. An external interlock jumper is installed on the power supply when the system is shipped to defeat this interlock. This jumper can be removed and replaced with an external interlock circuit.

External Switch Connector

The power supply is equipped with a passive electrical connector that is closed when the laser is on and open when the laser is off. This connector can be used to automatically control external devices, such as turning on external laser warning lights, when the laser tube ionizes.

External Shutter Interlock

This connector is located inside the laser head and is connected to the external shutter in the laser head. As long as the terminals are connected, the shutter can be operated from the remote control module. If the terminals are disconnected, the shutter will close regardless of the setting on the remote control module. This jumper can be replaced with an external switch to close the shutter without shutting the laser off.

Remote Control Module

The remote control module provides the operator with functional control and monitoring of the laser system. All system functions are available to the operator through the remote control module either by dedicated push-buttons or by menu selection. A 4.9 meter (16 ft.) cable connects the remote control module to the rear of the power supply.

The remote control module provides the following functions:

- Displays system status parameters.
- Displays fault messages.
- Allows one of two preselected operating levels to be selected by pressing a single push-button.
- Allows changing modes of operation.

The Sabre can also be controlled and monitored from an external computer or terminal. Refer to Chapter Eleven, External Computer Control, for additional information.

Remote Control Module Extension Cable

The standard cable connecting the remote control module to the power supply is 4.9 m (16 ft.) long. An optional extension cable which lengthens the standard cable to 7.6 m (25 ft.), is available. An RS-422 interface is used for the remote control module/power supply interface, allowing a maximum (shielded) cable length of 305 m (1000 ft.).

Heat Exchanger

The Sabre ion laser requires a flow of water to remove heat generated in the laser head and in the passbank in the power supply. Because the properties of the cooling water are critically important to the performance of the laser, the Sabre laser system is delivered with a separate heat exchange unit that connects to the power supply to form a closed water loop. This solution allows the quality of the water running through the laser to be carefully controlled which translates to longer life span of the plasma tube and less down time due to contaminated water. The use of the heat exchanger also improves beam pointing and power stability.

The heat exchanger incorporates a 55 kW heat exchanger and a pump circulating the internal cooling water through the power supply and the laser head. Electrical power for the is provided through a cable from the power supply. The pump is automatically switched on by the system software when the system start delay sequence is initiated and shut off approximately 5 minutes after the plasma tube is deionized.

An emergency shut off switch on the heat exchanger shuts off power to the heat exchanger pump. The function of the emergency switch is to turn off the water flow in the event of a leak at initial system installation.

The emergency switch should not be used as the primary means to switch off the laser system. Severe damage to the tube/magnet assembly may occur if the water flow is interrupted when the tube is ionized. Use the ON/OFF button located on the remote control module to shut the system down.

Maintenance Kit

A maintenance kit is supplied with each Sabre ion laser. This kit contains basic tools, materials, and parts for routine system maintenance as listed in Table 1-1.

Table 1-1. Maintenance Kit

ITEM	PURPOSE
Hemostats Acetone Methanol Lens cleaning tissue	Cleaning optics
Head interlock defeats (2)	Allows operation with the laser head sub-covers off. For maximum safety, use interlock defeats only when directed to do so by the procedures in this manual.
Allen wrench set	Allows adjustment, replacement and general maintenance of various components of the laser.
80 Amp line fuses (3)	Replacement main line fuses.
1/8 inch ball driver	Allows adjustment of various components of the laser, especially front mirror plate and etalon adjusts.
O-rings (2)	Used at umbilical to power supply interface.
Hose washers (10)	Used for power supply to heat exchanger to facility water connections.
1/4 inch socket driver	Used to secure umbilical to power supply
Foot clamps (2)	Used to clamp down laser head.

Operator's Manual

Chapter Two
System Specifications and Parameters

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Specifications

This section contains performance specifications for the INNOVA Sabre Ion laser system.

Output Powers

Argon Sabre systems are available in two basic tube configurations—tubes with two Brewster windows (DBW-dual Brewster window) and tubes with one window replaced by a sealed mirror (TSM-tunable sealed mirror). Krypton Sabre systems are available with dual Brewster window tubes only.

Table 2-1. Power Specifications For Argon Dual Brewster Window Systems

Argon Dual Brewster Window Systems						
Wavelength (nm)		Sabre Models				
		DBW 10	DBW 15	DBW 20	DBW 25	
Multiline Visible	**Standard**	**10**	**15**	**20**	**25**	
528.7	528.7 green option	0.8	1.0	1.4	1.8	
514.5	**Standard**	**5.0**	**7.0**	**9.0**	**10.0**	
501.7	blue-green option	0.8	1.0	1.4	1.8	
496.5	blue-green option	1.2	1.8	2.4	3.0	
488.0	**Standard**	**4.0**	**6.0**	**7.0**	**8.0**	
476.5	blue-green option	1.2	1.8	2.4	3.0	
472.7	blue-green option	0.4	0.6	1.0	1.3	
465.8	blue-green option	0.2	0.4	0.6	0.8	
457.9	457.9 blue option	0.8	1.2	1.4	1.5	
454.5	454.5 blue option	0.2	0.4	0.6	0.8	
		DBW 10 / 2	**DBW 15 / 3**	**DBW 20 / 4**	**DBW 25 / 5**	**DBW 25 / 7**
333.6 - 363.8	**Standard**	**2.0**	**3.0**	**4.0**	**5.0**	**7.0**
351.1	**Standard**	**0.6**	**0.8**	**1.2**	**1.5**	**1.8**
363.8	**Standard**	**0.6**	**0.8**	**1.2**	**1.5**	**1.7**
351.1 - 385.8	LUV option	1.2	2.0	2.8	3.6	4.4
300.3 - 335.8	SUV option	0.7	1.5	2.0	2.5	3.0
275.4 - 305.5	DUV option	0.3	0.6	0.9	1.2	1.6
275.4	275.4 only option	—	—	0.15	0.25	0.35

Table 2-2. Power Specifications For Argon Sealed Mirror Systems-Visible

Argon Tunable Sealed Mirror Systems - Visible region					
Wavelength (nm)		Sabre Models			
		TSM 10	TSM 15	TSM 20	TSM 25
Multiline Visible	**Standard**	**10**	**15**	**20**	**25**
514.5	**Standard**	**5.0**	7.0	9.0	**10.0**
501.7	blue-green option	0.8	1.0	1.4	1.6
496.5	blue-green option	1.2	1.8	2.4	3.0
488.0	**Standard**	**4.0**	**6.0**	**7.0**	**8.0**
476.5	blue-green option	1.2	1.8	2.4	3.0
472.7	blue-green option	0.2	0.5	1.0	1.3
465.8	blue-green option	0.1	0.4	0.6	0.8
457.9	457.9 blue option	0.8	1.2	1.4	1.5
454.5	454.5 blue option	-	-	0.3	0.5

Table 2-3. Power Specifications For Argon Sealed Mirror Systems-UV

Argon Tunable Sealed Mirror Systems - UV region						
Wavelength (nm)		Sabre Models				
		TSM 2	TSM 3	TSM 4	TSM 5	TSM 7
333.6 - 363.8	**Standard**	**2.0**	**3.0**	**4.0**	**5.0**	**7.0**
351.1	**Standard**	**0.6**	**0.8**	**1.2**	**1.5**	**1.8**
363.8	**Standard**	**0.6**	**0.8**	**1.2**	**1.5**	**1.7**
351.1 - 385.8	LUV option	1.2	2.0	2.8	3.6	4.4
300.3 - 335.8	SUV option	0.7	1.5	2.0	2.5	3.0
275.4 - 305.5	DUV option	0.3	0.6	0.9	1.2	1.6

Table 2-4. Krypton Multiline Power Specifications

KRYPTON MULTILINE OUTPUT POWERS			
Wavelength (nm)			Power (W)
752.5 - 799.3	MLIR	IR option	1.6
647.1 - 676.4	**MLRED**	**Standard**	**4.6**
520.8 - 568.2	MLYG	Yellow/Green option	3.3
468.0 - 530.9	MLBG	Blue/Green option	3.5
406.7 - 415.4	MLVI	Violet option	3.0
337.5 - 356.4	MLUV	UV option	2.0

Table 2-5. Krypton Single Line Power Specifications

KRYPTON SINGLE LINE OUTPUT POWERS		
Wavelength (nm)		Power (W)
799.3	IR option	0.3
752.5	IR option	1.2
676.4	**Standard**	**0.9**
647.1	**Standard**	**3.5**
568.2	Yellow/Green option	1.1
530.9	Yellow/Green option	1.5
520.8	Yellow/Green option	0.7
482.5	Blue/Green option	0.4
476.2	Blue/Green option	0.4
468.0	Blue/Green option	0.5
415.4	Violet option	0.28
413.1	Violet option	1.8
406.7	Violet option	0.9
350.7	UV option	0.8

The argon dual Brewster window configurations are recommended for applications which require several or all wavelength ranges from the visible to the deep UV. The krypton Sabre can cover wavelength ranges from the infrared to the UV. A variety of optional optic sets with different power specifications and wavelength ranges can be purchased with these configurations.

The argon tunable sealed mirror configurations are best suited for applications with defined wavelength regions. They offer almost identical multiline, single line, and single-frequency performance specifications as the dual Brewster window tubes with the benefit of even longer tube lifetime.

Output Beam Characteristics

Power stability, noise and beam pointing stability are measured at 514.5 nm for argon visible systems, 351.1 nm for argon UV systems, and 647.1 nm for krypton systems.

Table 2-6. Beam Specifications.

PARAMETER(1)	DESCRIPTION
Beam pointing stability (2):	
Angle	<5 μrad/°C
Offset at output coupler	<5 μm/°C
Long-term power stability(3):	
Light regulation	± 0.5%
Current regulation	± 1.0%
Optical Noise (RMS) (4):	
Light regulation	± 0.2%
Current regulation	± 0.2%

The above specifications subject to change without notice.

(1) All performance specifications are measured at the specified output at 514.5 nm for argon visible systems, 351.1 nm for argon UV systems, and 647.1 nm for krypton systems.

(2) Beam pointing and offset are measured per °C change of ambient air or cooling water temperature.

(3) Maximum peak variation after a 15 minute warm-up.

(4) Measured with a 10 Hz to 2 MHz photodiode driving a resistive load.

Beam Parameters

The following beam parameters are measured values for selected argon and krypton single lines. Intracavity absorption even as low as 0.05% typically creates some thermal lensing which impacts the beam parameters. Beam diameter, waist diameter and divergence are less effected and are typically within ±5% of the values in Tables 2-7 and 2-8. Since ion laser beams have very low divergence, even a small amount of thermal lensing has a more significant effect on beam waist location.

Table 2-7. Argon Beam Parameters

BEAM PARAMETERS	514.5 nm	351.1 nm
Beam Diameter @ $1/e^2$ points at output coupler	2.1 mm	1.7 mm
Beam Divergence (full angle)	0.35 mrad	0.31 mrad
Virtual Beam Waist Diameter @ $1/e^2$ points	2.0 mm	1.6 mm
Virtual Beam Waist Location (Measured from the output coupler toward the rear mirror)(1)	–2.5 m	–2.5 m
Beam polarization	100:1, vertical	

(1) The beam waist is located at the flat high reflector inside the resonator . The long-radius output coupler acts as a weak lens to transform the output beam parameters. The values listed for beam divergence takes into account the weak lens effect.

Table 2-8. Krypton Beam Parameters

BEAM PARAMETERS	647.1 nm	413.1 nm
Beam Diameter @ $1/e^2$ points at output coupler	2.0 mm	1.6 mm
Beam Divergence (full angle)	0.50 mrad	0.40 mrad
Virtual Beam Waist Diameter @ $1/e^2$ points	1.6 mm	1.3 mm
Virtual Beam Waist Location (Measured from the output coupler toward the rear mirror) (1)	–2.4 m	–2.4 m
Beam polarization	100:1, vertical	

(1) The beam waist is located at the flat high reflector inside the resonator. The long-radius output coupler acts as a weak lens to transform the output beam parameters. The values listed for beam divergence takes into account the weak lens effect

Single-Frequency

Optimal single-frequency performance by Sabre is provided by three types of elaton optics dependent on system type and wavelength range. For more information, refer to Chapter Eight, Single-Frequency Operation.

Table 2-9. Optional Argon Single-Frequency Power Specifications - Visible

ARGON SINGLE-FREQUENCY POWERS - VISIBLE REGION				
Wavelength (nm)	Sabre Models			
	TSM 10 DBW 10	TSM 15 DBW 15	TSM 20 DBW 20	TSM 25 DBW 25
514.5	3.0	4.2	5.4	6.0
488.0	2.4	3.6	4.2	4.8
457.9	0.5	0.7	0.8	0.9

Table 2-10. Optional Argon Single-Frequency Power Specifications - UV

ARGON SINGLE-FREQUENCY POWERS - UV REGION					
Wavelength (nm)	Sabre Models				
	DBW 10/2 TSM 2	DBW 15/3 TSM 3	DBW 20/4 TSM 4	DBW 25/5 TSM 5	DBW 25 /7 TSM 7
351.1	0.35	0.5	0.7	0.85	1.0
363.8	0.35	0.5	0.7	0.85	1.0

Table 2-11. Optional Krypton Single-Frequency Power Specifications

KRYPTON SINGLE-FREQUENCY POWERS	
Wavelength (nm)	Power (W)
647.1	1.75
413.1	0.9
350.7	0.4

Table 2-12. Single-Frequency Performance

Frequency Drift:(1)	≤ 30 MHz/°C
Ambient air temperature range for ν-Track:	±10°C
Warm-up time to mode-hop free operation:	30 minutes for first time operation(2) 5 minutes for repeat operation (3)

(1) With ν-Track engaged. Water temperature is regulated to ±1°C by the Sabre heat exchanger. The frequency drift specification applies to ambient air temperature changes.

(2) ModeTune needs to be run when operating at a new laser line for the first time. ModeTune finds the etalon temperature for optimum single-frequency operation which takes approximately 15 to 25 minutes.

(3) This specification requires that the keyswitch remains on while the system is off. The etalon optic is kept at the correct temperature with the keyswitch on. ν-Track can be engaged in this case after a few minutes of operation.

System Parameters

Table 2-13. Operating Tube Voltage/Current Range

LASER MODELS	NOMINAL TUBE VOLTAGE AT MAXIMUM TUBE CURRENT	MAXIMUM TUBE CURRENT
DBW 10, DBW 10/2 TSM 10, TSM 2	480 V	50 A
DBW 15, DBW 15/3 TSM 15, TSM 3	505	55
DBW 20, DBW 20/4 TSM 20, TSM 4	520	60
DBW 25, DBW 25/5, DBW 25/7 TSM 5, TSM 7	533	65
TSM 25	538	65
Krypton Sabre	520	65
The above specifications subject to change without notice.		

System Weight and Dimensions

Table 2-14. System Weights

	LASER HEAD	POWER SUPPLY	HEAT EXCHANGER
Crated	195 kg (430 lbs)	134 kg (295 lbs)	102 kg (225 lbs)
Uncrated	109 kg (240 lbs)	107 kg (235 lbs)	75 kg (165 lbs)
The above specifications subject to change without notice.			

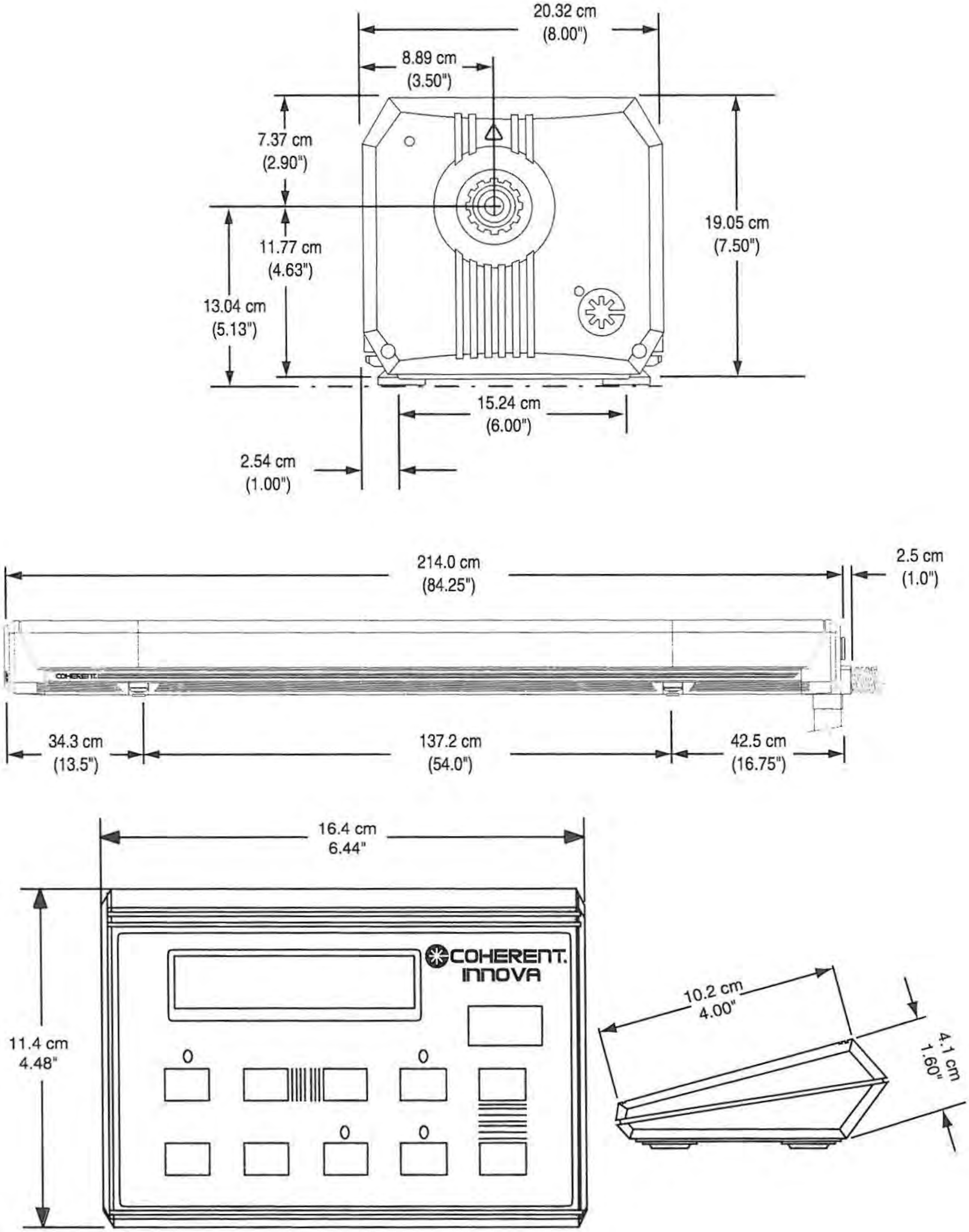


Figure 2-1. System Dimensions

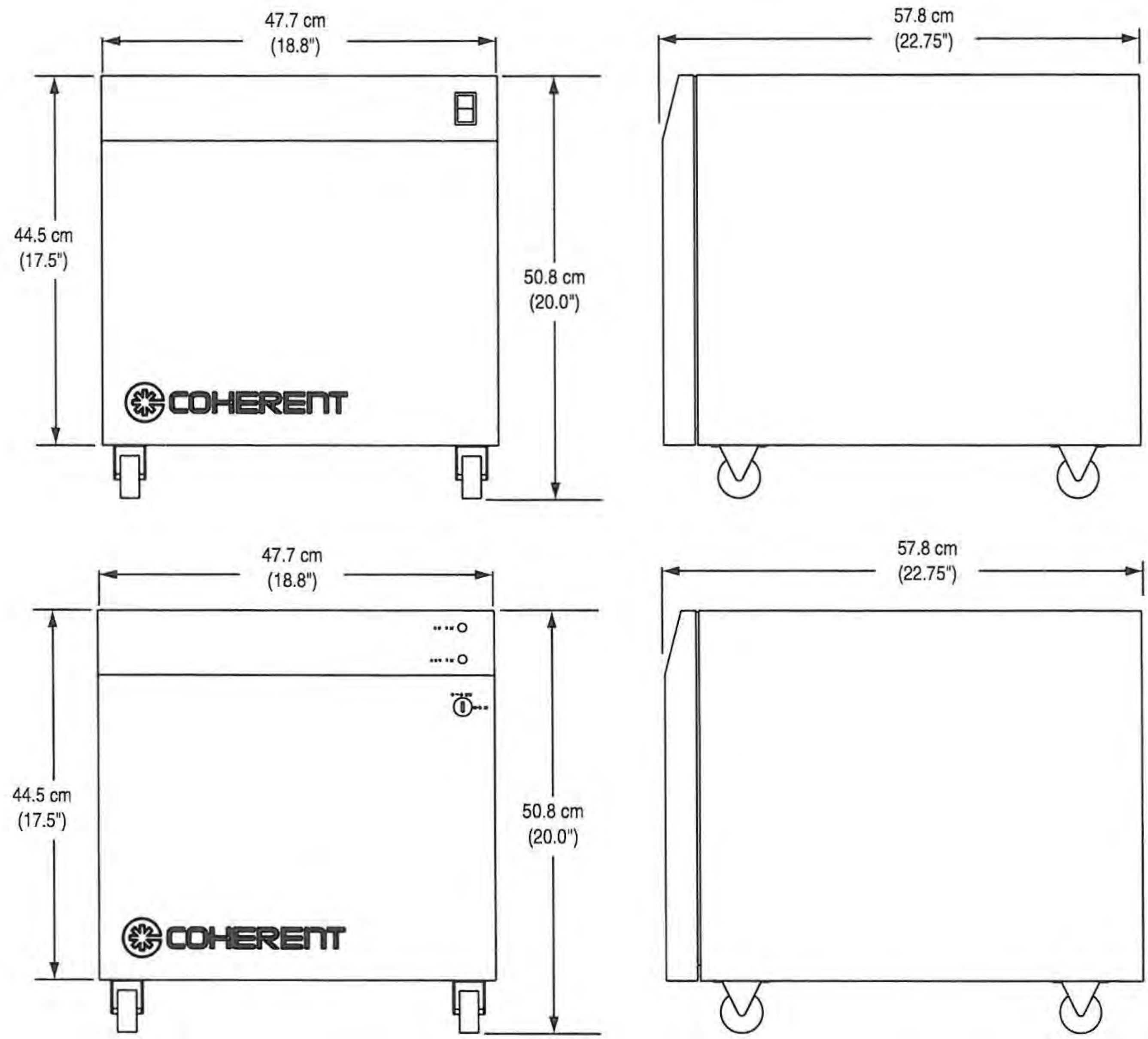


Figure 2-1. System Dimensions, continued

Operator's Manual

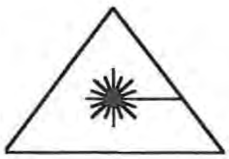
Chapter Three
Laser Safety

Coherent

Optical Safety

The INNOVA Sabre ion laser is a precision laser and has undergone extensive testing to ensure that, with proper usage, it is a safe and reliable tool.

Laser light, because of its special properties, poses safety hazards not associated with light from classical sources. The safe use of lasers requires that all laser users and everyone working near a laser be aware of the dangers involved.



Direct eye contact with the output beam from the Sabre will cause serious damage and possible blindness.

All personnel in the same room as the laser or anyone who may be exposed to the laser beam should be informed that a laser is in operation. All personnel must wear laser safety glasses which protect against the wavelengths in use.

The greatest concern when using a high power laser such as the Sabre ion laser is eye safety. In a complex optical set up, there are often many smaller beams present at various angles near the laser. These beams are formed by specular reflections of the main beam from polished surfaces such as lenses or beamsplitters. While weaker than the main beam, such beams may still be sufficiently intense to cause eye damage.

Laser beams are also powerful enough to burn skin, clothing or paint. They can ignite volatile substances such as alcohol, gasoline, ether and other solvents and can damage the light-sensitive elements in video cameras, photomultipliers and photodiodes.

The following recommendations are provided by Coherent to promote the safe use of the Sabre ion laser. Operators of the Sabre ion laser are advised to adhere to these recommendations and to employ sound laser safety practices at all times.

- Use protective eyewear whenever you operate the laser and guard against inadvertent exposure to skin or clothing. Select eyewear which is suitable for use with the wavelengths and radiation intensity that the laser produces. Refer to the Laser Focus World Buyer's Guide or the Rockwell Laser Industries catalogue for suppliers of protective eyewear.
- Wavelengths shorter than 400 nm (UV) are invisible to the eye. When operating the laser in UV, take extra care to use appropriate eyewear and to avoid inadvertent

exposure to skin or clothing. In addition, assure that the work area has adequate ventilation to minimize the risk from formation of toxic compounds due to interaction of the laser beam with the atmosphere.

- Do not remove protective covers from the laser head. During normal operation, internal reflections are confined within the laser head and pose no safety hazard.
- Never look directly into the laser output port when the power is on.
- Do not stare at laser light reflected from any surface.
- Set up the laser and all experimental apparatus used with the laser below or above eye level. Provide enclosures for the laser beam.
- Use the laser in a room with access controlled by door interlocks. Post warning signs. When operating the laser, limit access to the area to individuals who are trained in laser safety.
- Avoid operating the laser in a darkened environment.
- Do not use the laser in the presence of flammables, explosives, or volatile solvents such as alcohol, gasoline, or ether.

For additional information on laser safety, refer to the following publications:

- Laser Safety Comes to Light (videotape). ©Coherent, Inc., 1988.
- American National Standard for the Safe Use of Lasers. Z136.1-1993. American National Standards Institute, 1993.
- Performance Standard for Laser Products. FDA., (FR-40) (148): 32252-32265. Department of Health, Education and Human Service. Bureau of Radiological Health, July 31, 1974.
- Laser Safety Guide, Laser Institute of America. (9th Edition). Orlando, FL 1993.
- D. Sliney and M. Wolbarsht: Safety with Lasers and Other Optical Sources, Plenum Publishing Company, New York, N.Y., 1980.

Electrical Safety

Sabre ion lasers are designed to meet UL1262 and IEC1010 Standards for Electrical Safety of Laboratory Equipment. Sabre ion lasers are operated by high voltage DC power rectified directly from a 480 VAC, 3-phase power line. These voltages are sufficient to give a lethal shock. Every portion of the electrical system, including the printed circuit boards, should be considered to be at a dangerous voltage level. All the metal parts of the plasma tube, including the fill system, should be considered extremely dangerous.

The laser head is equipped with safety interlocks on the access covers. Removal of these covers during operation will cause the laser to cease operation. Turn the laser off before removing any covers.

The Sabre ion laser system has been designed to provide protection to the operator in the event of any single component failure, provided that the system is installed and operated properly as described in the operator's manual. All laser users should read, understand, and follow the safety warnings and operating instructions contained within the operator's manual.

Because the manufacturer is unable to guarantee the safety of laser users in the event of two independent component failures, this equipment must not be operated if there is evidence of any personnel hazard, component failure, improper installation, or significant damage. The failure of a single component is not hazardous, but may allow for no protection against, or warning of, a hazardous condition if another failure occurs. Routinely inspect the laser system for evidence of potential safety hazards or component failures.

Some examples of failure or damage are: physical damage to the external covers; evidence of loose, missing, or broken parts (either internal or external); water leaks; blown fuses; disconnected, partially connected or broken electrical connectors; cut, missing, or damaged wire or cable insulation; electric shock, sparks, or other indications of dangerous accessible voltages; missing or improperly functioning safety related subsystems (shutters, interlocks, warning lights, etc.); evidence of smoke, fire, or excessive heat; disconnection of, or damage to the protective earthing cables (cover grounding system). There may be other indications of failure, damage, or a safety hazard which are not listed above.

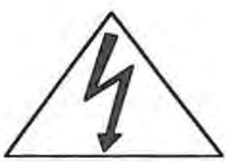
If it suspected that the laser system is missing safety related parts, has been damaged, or may otherwise be unsafe, turn the laser off, and disconnect the input power immediately.

Do not operate the laser until all potential safety hazards have been eliminated. Do not attempt to use any tool to remove covers to investigate or repair the equipment unless specifically trained to service this equipment. In any case, any attempt to repair this laser is done at the users own risk. Improper repairs or modifications may be hazardous during the repair, or may create a hazardous situation at some later time.

Call Coherent technical support for help in determining if your equipment is safe, to schedule repairs, or to arrange for training on laser use or repair (training is not necessarily available for all systems).

Laser Head

High voltages are present in the laser head when the power is on. The head cover is interlocked and should not be opened during normal operation. Maintenance procedures located in this manual require opening of the cover. Please read the appropriate manual sections carefully before attempting any maintenance of components housed in the laser head.



If the laser head cover is off while the laser is operating, assume that all metal parts of the plasma tube are at HIGH VOLTAGE.

Laser Safety Features and CDRH Compliance

The following features are incorporated into the instrument to provide conformity to United States Government requirements 21 CFR subchapter J, administered by the CDRH (Center for Devices and Radiological Health).

Protective Housing

The laser head is enclosed in a protective housing that prevents human access to radiation in excess of the limits of Class I radiation as specified in the Federal Register, July 31, 1975, Part II, Section 1040.10 (f) (1) and Table 1-A except for the output beam, which is Class IV.

Safety Interlocks

The laser head cover is equipped with interlocks that prevent the laser from operating with the head cover removed.

Means are provided to defeat these interlocks only for maintenance operations. Only qualified personnel familiar with high voltage electronics should perform maintenance on the power. Use extreme caution when the laser is operated with the interlocks defeated. There is the danger of electrical shock and eye injury which may result in permanent blindness (CFR 1040.10(f)(2)).

External Interlock Connector

Terminals on the rear of the power supply are provided for an external interlock connection. These terminals must be connected for the laser to operate. This connector is jumpered when the laser shipped but can be removed and replaced with an external interlock circuit (CFR 1040.10(f)(3)).

Key Control

The instrument cannot be turned on or operated until the system key switch is in the ON position (CFR 1040.10 (f)(4)).

Laser Radiation Emission Indicators

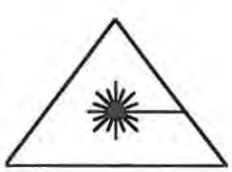
The appropriately labelled lights on both the remote control module and the laser head are turned on approximately 75 seconds before laser emission can occur. White lights are used so that they will be seen regardless of the type of safety glasses which might be used (CFR 1040.10(f)(5)).

Intracavity Shutter

This manually operated shutter can block all bodily access to laser radiation without turning off the laser (CFR 1040.10(f)(6)).

Operating Controls

Electronic controls are located on the remote control module and are positioned so that the operator is not exposed to laser emission while manipulating the controls (CFR 1040.10(f)(7)).



Use of controls or adjustments, or performance of procedures other than those specified herein, may result in hazardous radiation exposure.

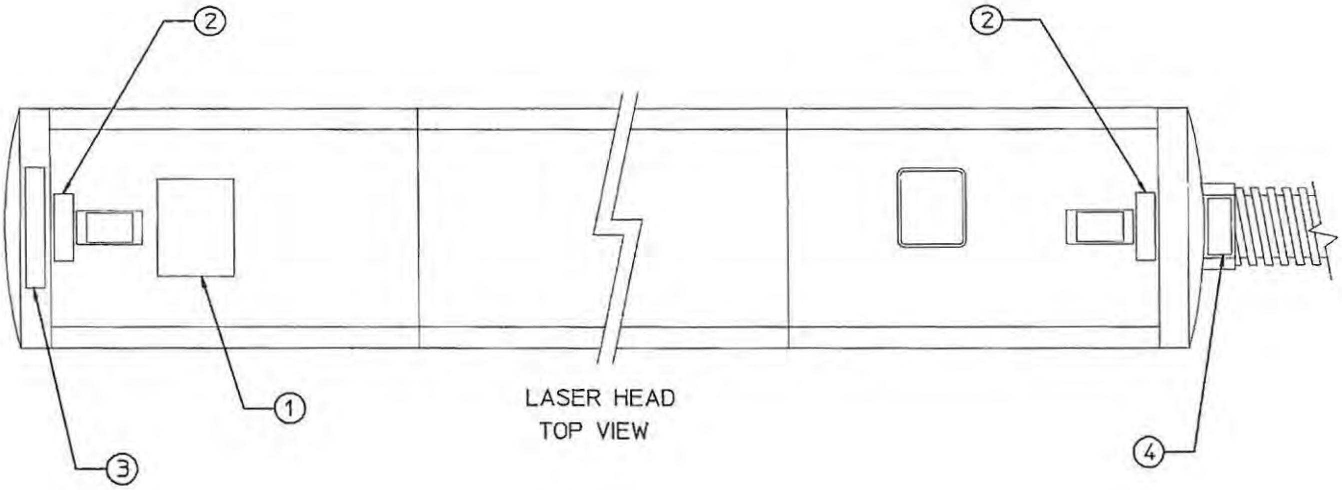
Location of CDRH Compliance Labels

Refer to Figure 3-1 for a description and location of all CDRH required labels. These include warning labels indicating removable or displaceable protective housings, apertures through which laser radiation is emitted and labels of certification and identification (CFR 1040.10(g)), (CFR 1010.2), and (CFR 1010.3).

Use of the INNOVA Sabre for Light Shows

The U.S. Food and Drug Administration has special requirements for lasers intended to be used for light show or demonstration purposes within the United States.

As a Class IV laser system, the Sabre ion laser complies with all safety and performance standards. However, additional certification is required to assure that suitable means of radiation safety and protection will be provided by the light show producer. Please contact the FDA Office of Compliance at 301-427-1172 for further information about laser certification for light shows or demonstrations.



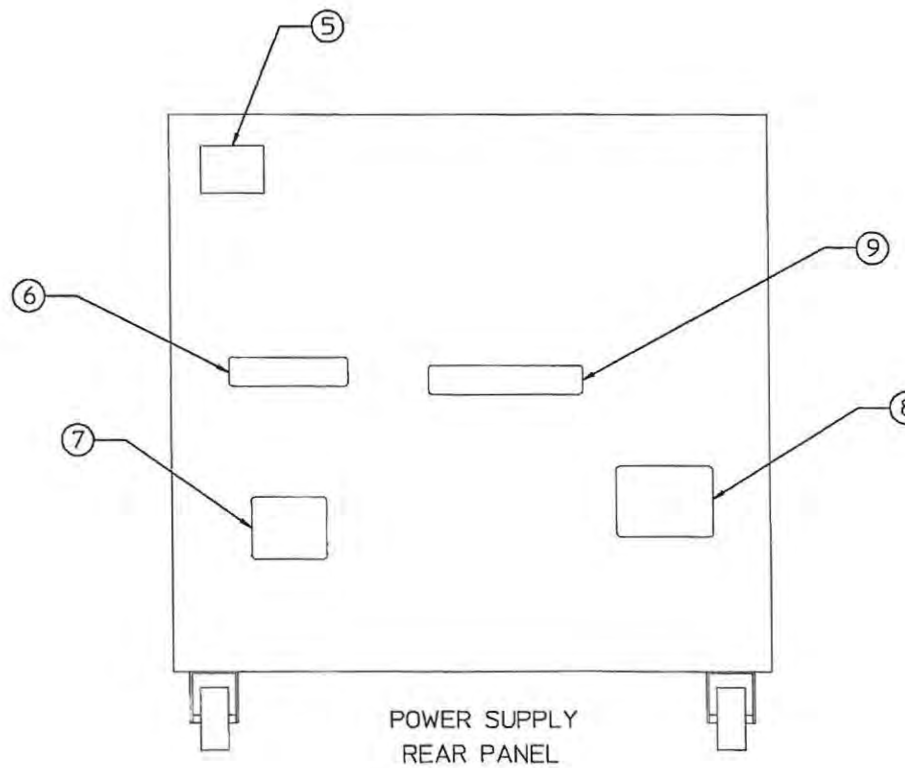
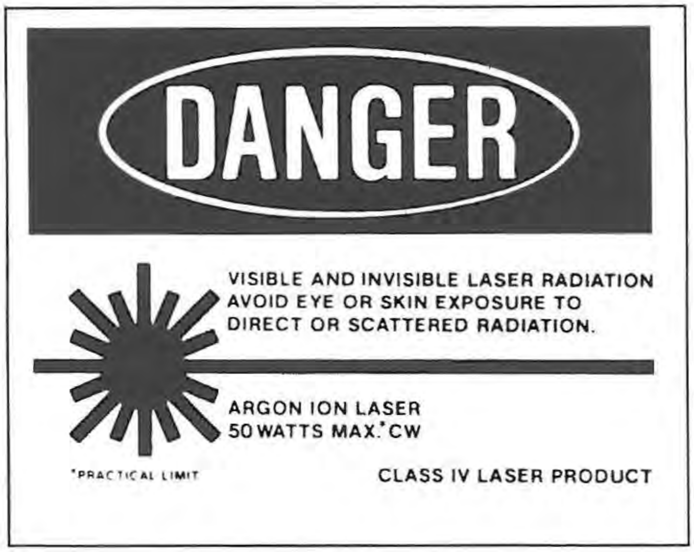


Figure 3-1. Locations of Safety Labels (Sheet 1 of 3)



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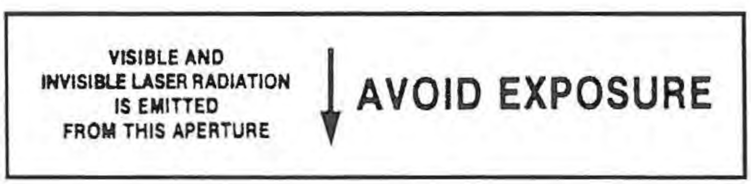

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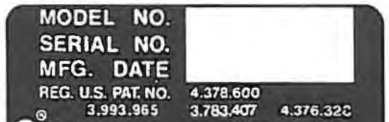

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Figure 3-1. Locations of Safety Labels (Sheet 2 of 3)

THIS PRODUCT COMPLIES WITH DHHS RADIATION
PERFORMANCE STANDARDS 21 CFR SUBCHAPTER J
EXCEPT WITH RESPECT TO THOSE CHARACTERISTICS
AUTHORIZED BY VARIANCE NUMBER 89V-0201
EFFECTIVE JULY, 1989

MODEL NO.

SERIAL NO

MANUFACTURED

COHERENT
3210 PORTER DR PALO ALTO, CA

MADE IN
U.S.A.

5

FUSE 80A 500V~IEC269–2 100kAIC
REPLACE ONLY WITH FUSES OF
THE SAME TYPE AND RATING

6

INPUT POWER:
480V AC, 3 PHASE,
50/60Hz, 65A/PHASE
PHASE ROTATION IS
BRN–BLU–BLK
GROUND CONNECTION
IS REQUIRED

7

TB1

1, 2 — EXTERNAL INTERLOCK, CONNECT TERMINALS FOR LASER OPERATION

3, 4 — SWITCH, CLOSED WHEN LASER IS ON 600V AC, 12A MAX NOT FUSED

8

CAUTION–DANGEROUS VOLTAGES
UNDER THESE COVERS. DISCONNECT
INPUT POWER BEFORE OPENING

9

Figure 3-1. Location of Safety Labels (Sheet 3 of 3)

OPERATOR'S MANUAL

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CHAPTER FOUR
UTILITY REQUIREMENTS AND SYSTEM INSTALLATION

COHERENT

Introduction

Although some initial tasks can be performed by the customer, first system turn-on must only be performed by a Coherent service engineer.

Utility Requirements

The Sabre ion laser requires electrical power and cooling water for the system. The electrical power must meet the specifications in Table 4-1. The pressure and temperature requirements for the cooling water is shown in Figure 4-1.

Electrical Service

The electrical service needs to be three phase 480 VAC in WYE configuration, with no neutral and the yellow/green wire to building ground. There is no neutral connection. The Sabre system will operate with either 60 Hz or 50 Hz line frequency.

Electrical power must meet the specifications in Table 4-1. The power supply is delivered with a 3 m (10 ft.) power cable without a connector attached to the free end unless otherwise specified at the time of order. The cable is type HAR-4/4, #4 AWG, four wires. You must provide the hardware necessary to connect this cable to your electrical service. The facility outlet must have a fuse or circuit breaker on each phase. Consult applicable local electrical codes to select this hardware.

In addition, Coherent recommends that a main power disconnect be located in the same room as the laser system. Consult applicable electrical codes for your area to select this hardware.

Table 4-1. Utility Requirements

ELECTRICAL:	
Line voltage:	480 VAC ±10% (1), 3-phase in WYE configuration with ground, no neutral; 70 Amps per phase (2). Phase balance <3% between phases.
Line frequency:	50/60 Hz
Maximum power consumption:	55 kW
ENVIRONMENTAL:	For optimum performance, the laser should be located in a room maintained at a temperature of 10 to 40°C (50 to 104°F).

(1) The laser system will operate properly between 432 VAC and 528VAC provided that the voltage between each pair of phases is within 3% of each other. Power companies almost always provide balanced 3-phase power, but if a heavy load is connected asymmetrically, the line balance can be disturbed. This results in excessive ripple current through the capacitors of the DC filter. This ripple current degrades the noise performance of the laser and shortens the lifetime of the filter capacitors.

(2) This is the actual maximum continuous current drawn by the laser.

Cooling Water

The Sabre ion laser requires a flow of water to cool the laser head and electrical components inside the power supply. Because the properties of the cooling water are critically important to the performance of the laser, the Sabre is delivered with a separate heat exchanger that connects to the power supply to form a closed water loop. This allows the quality of the water through the laser system to be carefully controlled which translates to longer life span of the plasma tube. It also eliminates condensation as a source of system failure. The use of a heat exchanger also improves beam pointing and power stability since the heat exchanger regulates the cooling water temperature within ±1 °C (±1.8 °F). The plant water required for the water to water heat exchanger can be either tap water or any closed loop water cooling system. The requirements for the plant water are illustrated in Figure 4-1.

Figure 4-1 shows the minimum requirements for the plant water for the nominal maximum heat load of 55 kW. The laser water inlet temperature is set at 35 °C (95 °F). The laser system includes a set of 7.6 m (25 feet) hoses (3/4" inner diameter) between the customer water supply and the heat exchanger.

The maximum plant water temperature is 30 °C (86 °F), since the heat exchanger needs a minimum of 5 °C (9 °F) between plant side and laser side water temperature and the maximum laser cooling water temperature is 35 °C (95 °F). The required plant water flow at 30 °C (86 °F) is 57 liters/minute (15 GPM) to remove a heat load of 55 kW. In that case the required plant water pressure is 415 kPa (60 psig). This is the most extreme situation with the laser system at it's upper limit for cooling capacity.

A more typical installation uses plant water at 18 °C (64 °F). If the laser cooling water temperature is set to 35 °C (95 °F) the plant water flow is only 15 liters/minute (4 GPM) with a pressure requirement of only 37 kPa (5.4 psi). If the laser cooling water temperature is set to 30 °C (recommended) the plant water flow is 27 liters/minute (7 GPM) with a pressure requirement of 83 kPa (12 psi).

The laser cooling water properties are maintained by the heat exchanger and the deionizing cartridge. A summary of these properties are given in Table 4-2.

It is advisable to check local and state regulations which may control the use of city water for cooling. Some regulatory codes will not allow the discharge of cooling water into the sewer system.

Do not use de-ionized water in the internal cooling loop.

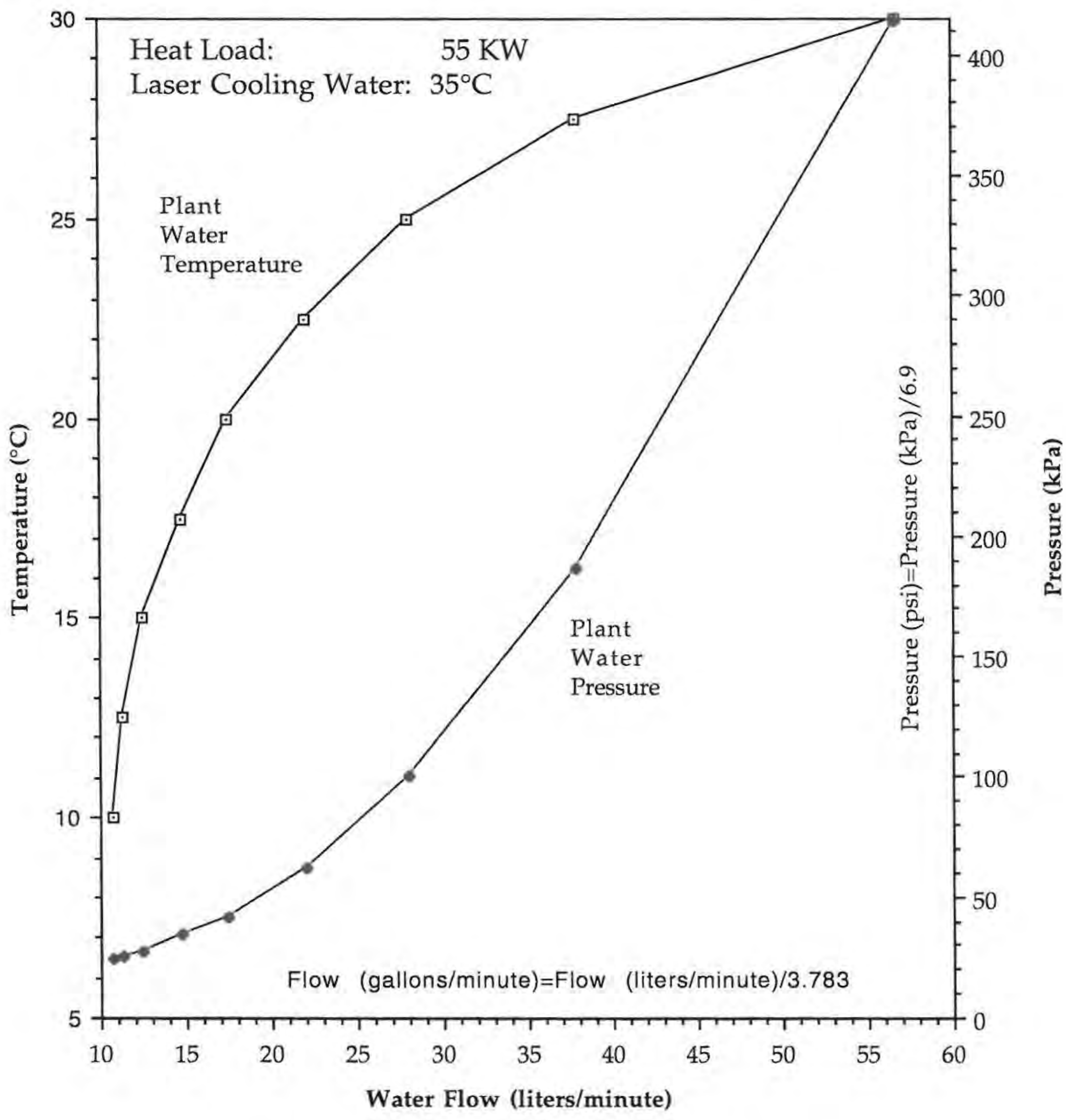

Figure 4-1. Minimum Plant Water Requirements

Table 4-2. Laser Cooling Water Properties

LASER COOLING WATER: Hardness:	<100 mg/liter (5.9grains/gallon) or 100 parts per million of calcium
Resistivity	50 kΩ-cm to 2.0MΩ-cm; (>100kΩ-cm recommended) Resistivity <100 kΩ-cm: Warning to replace cartridge
pH	6 to 8
Particulate size:	<200 microns in diameter
Heat load:	55 kW
Pressure differential (1):	240 kPa (35 psi) at 22.7 liters/minute (6.0 gallons/minute) (2)
Maximum static pressure (3)	620 kPa (90 psi)
Inlet temperature:	20°C to 35 °C (50 to 95 °F) (4)

(1) The pressure differential is the inlet pressure minus the drain pressure.

(2) Standard system with 7.6 m distance (25 feet) between facility water and heat exchanger; (3/4" diameter hoses).

(3) The static pressure is the inlet pressure measured under conditions of zero flow.

(4) The temperature control valve should be set to a temperature between 20 °C (68 °F) and 35 °C (95 °F) [30 °C (86 °F) recommended] to avoid condensation inside the laser system in case of high humidity.

Site Preparation

To assist in planning the work space, the dimensions of the components constituting the Sabre system are listed in Table 4-3. Enough space should be left around the laser head so that the components inside can be accessed. The laser head and power supply are connected through a 3 m (10 ft.) umbilical. When planning the work space, allow sufficient space to avoid bending or crimping the umbilical sharply. Allow for a bend radius of at least 30 cm (12 inches). In order to maximize the system's immunity to externally generated electromagnetic interference, take care not to route system cables in close proximity to other equipment cables.

The Sabre ion laser is a precision instrument whose performance depends on its environment. Vibrations can be transmitted to the laser head from the surface on which it rests, causing beam pointing instability and power fluctuations. To minimize vibrations, the laser head should be placed on a stabilized optical table and isolated from mechanical contact with other equipment.

Argon Sabre systems equipped with the deep or short UV options include purge kits. The purge kit consists of a variable flowmeter, necessary connectors and hoses, and special intracavity parts. A user-supplied source of dry nitrogen is required on purged systems. The recommended

grade of bottled nitrogen has a minimum purity of 99.999% and is sometimes known as scientific grade. A high purity "boil-off" nitrogen source may be used as an alternative. Dry air may not be used as it contains oxygen which can be converted to ozone by the deep UV produced by the plasma discharge.

Table 4-3. System Dimensions

	LENGTH	WIDTH	HEIGHT
Laser Head	216.5 cm (85.25")	20.3 cm (8")	19.1 cm to 20.4 cm (7.53" to 8.03")
Power Supply	57.8 cm (22.75")	47.8 cm (18.8")	50.8 cm (20.0")
Heat Exchanger	57.8 cm (22.75")	47.8 cm (18.8")	50.8 cm (20.0")

Unpacking the System

The Sabre ion laser is shipped in three crates: one contains the power supply, one the heat exchanger and the third the laser head. Accessories, including the remote control module, are packed in separate boxes and shipped in the laser head crate. A packing list, which details all the ordered items, is included in the shipment. Please check items received against this packing list.

Please advise your receiving department to perform the damage inspection procedure prior to signing the bill of lading.

Damage Inspection

Carefully inspect each crate and note any damage. All Sabre ion laser crates are shipped with rough handling indicators affixed to their front and back. Examine these indicators upon receipt. If the indicator bar is red, the crate has received handling which may have damaged the contents. Indicate any such signs on the bill of lading.

Report any damage immediately to the shipping carrier and to the Coherent Order Administration Department, 800-438-6323.

Uncrating

To minimize the risk of functional or cosmetic damage to your laser system, uncrate the laser head and power supply at the installation site.

To prevent serious damage, care must be taken when cutting wrapping materials from any of the items contained in the crates, particularly around the laser head and the umbilical.

Keep all shipping containers. If you file a claim for shipping damage, the containers may be needed to support the claim. In addition, if you return the laser system to Coherent for service, these containers will protect the system in shipment.

Unpacking the Laser Head

Loosen the retaining clips and remove the cover of the box containing the laser head.

1. Remove the accessory boxes from the head crate.
2. Carefully remove the umbilical from the crate.
3. Remove the laser head from the crate and set it on the work bench (at least two people required).

Leave the ESD (ElectroStatic Discharge) protective foam padding on umbilical until ready to connect it to the power supply.

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4. Remove the plastic wrapping from the umbilical at the rear end of the laser head.
5. Remove the water and power connectors from their plastic bags and protective foam padding.
6. Remove and retain the rectangular plug from the water connectors.

Unpacking the Power Supply

Loosen the retaining clips and remove the cover of the box containing the power supply.

1. Remove the foam padding from the top of the power supply.
2. Lift the power supply out of the crate and carefully set it on a flat, stable surface (at least two people required).
3. Remove the plastic bag from the top of the power supply.
4. Remove and retain the black rectangular plate covering the water connectors.
5. Take the key out of the maintenance kit and insert it into the lock on the front of the power supply.

Unpacking the Heat Exchanger

Follow the above instructions for the power supply. There is no key switch on the heat exchanger.

Installation

Refer to Figure 4-2 for all interconnections.

Placement of Power Supply and Heat Exchanger

Both power supply and heat exchanger are designed to fit next to each other under tables that have at least 53 cm (21 inches) of clearance. The connecting cable and water hoses are 4.6 m long (15 feet), if a different placement is desired.

Connecting the Umbilical

Ensure that the o-rings on the rear of the power supply are properly seated before connecting the umbilical. Insert the umbilical into the power supply receptacle as shown in Figure 4-3. Tighten the central bolt using a 1/4" Allen wrench.

To avoid crimping the umbilical, use a bend radius of at least 30 cm (12 inches).

Connecting the Remote Control Module

Connect the remote control module to connector J84, REMOTE MODULE on the rear panel of the power supply.

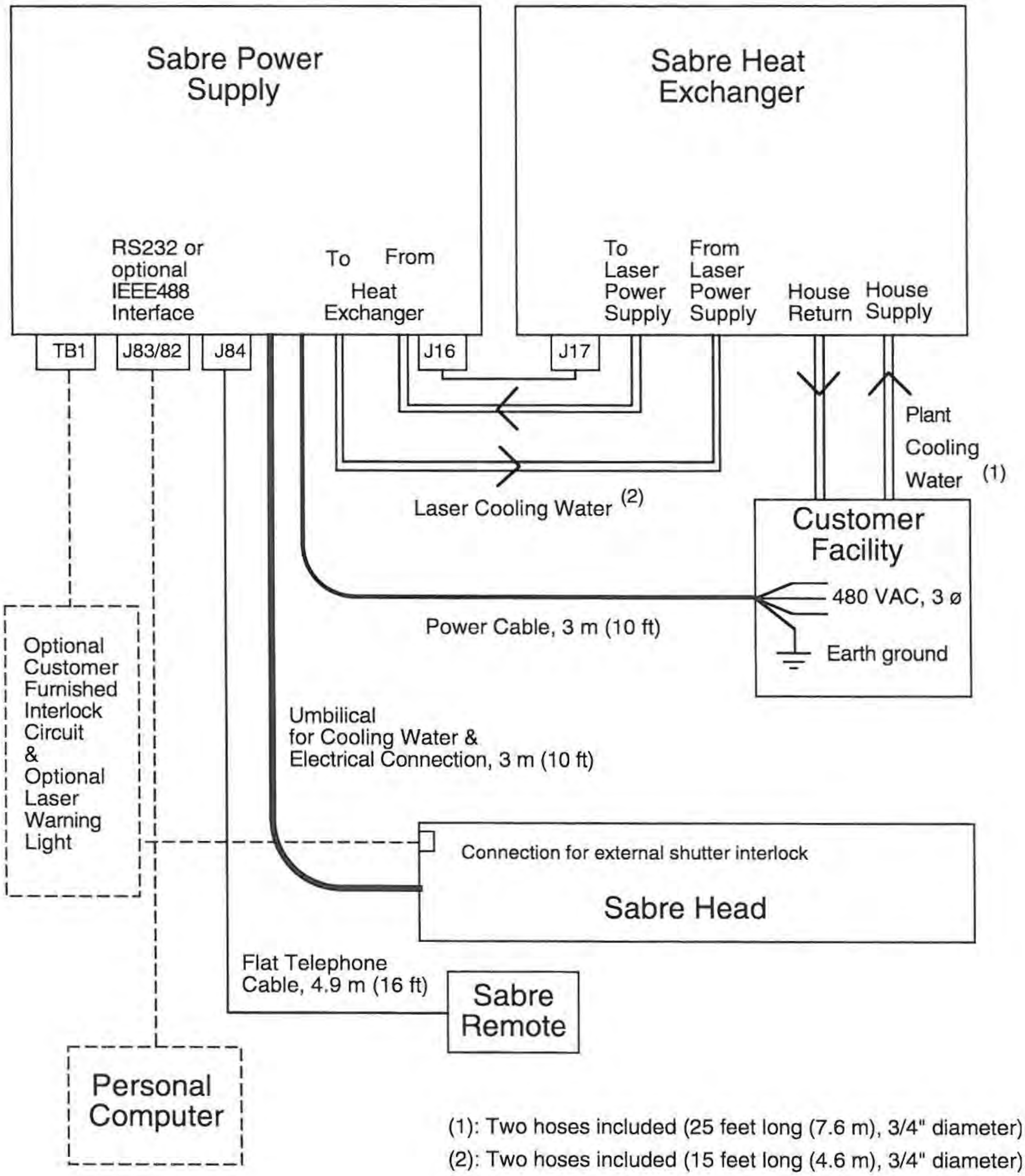
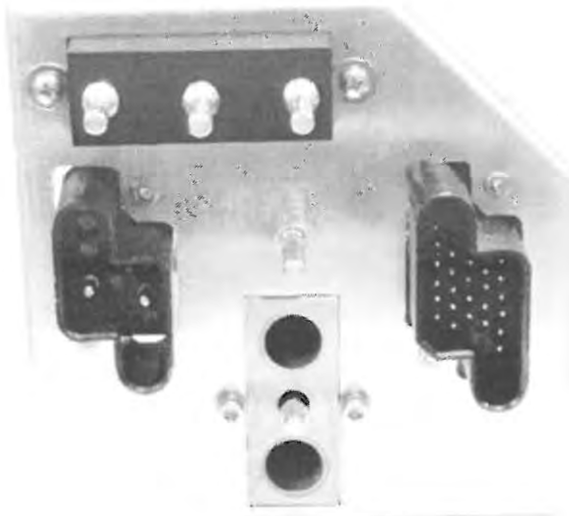
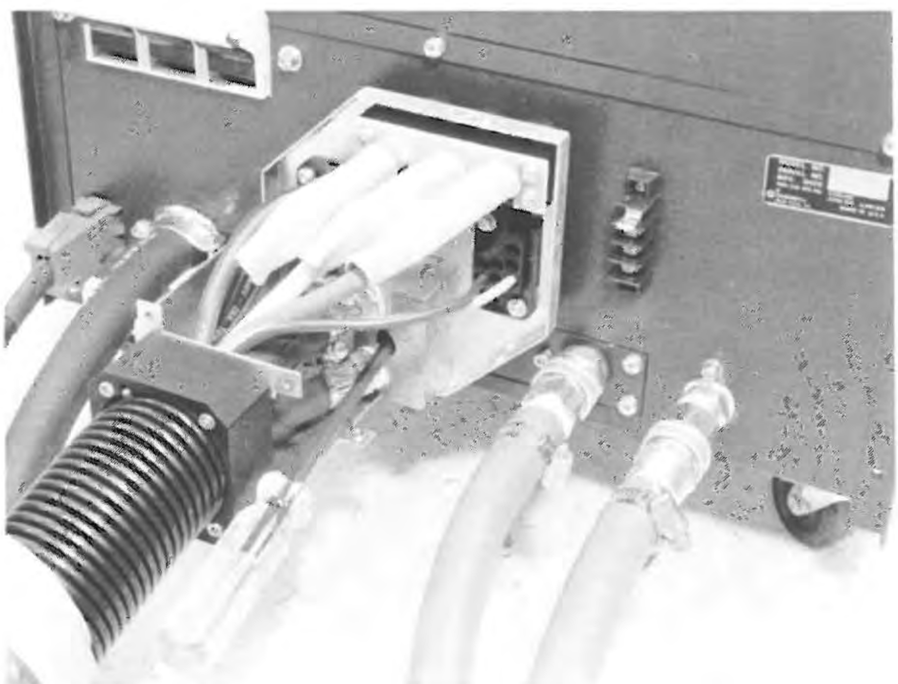


Figure 4-2. System Interconnection Diagram



A. Umbilical connector prior to installation



B. Connecting the umbilical to the power supply

Figure 4-3. Umbilical to Power Supply Connection

Connecting the Heat Exchanger

1. The Temperature Regulation Valve of the heat exchanger is factory set for 30 °C (86 °F), which is the recommended temperature setting, as shown by the label on the valve stem. For initial water leak testing, it is recommended to set the Temperature Regulation Valve to it's lowest setting (below the 1-mark on the valve body, about 6 clockwise revolutions). This ensures full facility water flow for leak testing after the heat exchanger is connected to the facility water supply.

   At this point, it is also recommended to fully open the Flow Regulation Valve, such that the handle is horizontal, for initial start-up of the heat exchanger.

2. Attach the control cable between the J17 connector of the heat exchanger and the "To Heat Exchanger" connector of the power supply.

3. Ensure that hose washers are installed in all of the hoses and the appropriate connectors on the power supply and heat exchanger.

4. Attach the 4.6 m (15 foot) hose with the female connector to the hose connector labeled TO LASER POWER SUPPLY on the heat exchanger rear panel. Attach the other end to the hose connector labeled FROM HEAT EXCHANGER on the power supply rear panel.

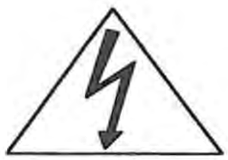
5. Attach the 4.6 m (15 foot) hose with the male connector to the hose connector labeled FROM LASER POWER SUPPLY on the heat exchanger rear panel. Attach the other end to the hose connector labeled TO HEAT EXCHANGER on the power supply rear panel.

6. Attach the 7.6 m (25 foot) hose with the female connector to the hose connector labeled HOUSE RETURN on the heat exchanger rear panel. Attach the other end to the facility drain outlet. A drain valve is recommended in case of a closed loop cooling system.

7. Attach the 7.6 m (25 foot) hose with the male connector to the hose connector labeled HOUSE SUPPLY on the heat exchanger rear panel. Attach the other end to the facility water supply. A supply valve is recommended. Do not turn on the water supply at this point yet.

The heat exchanger and the laser system is shipped with all water drained. Filling and priming the heat exchanger with

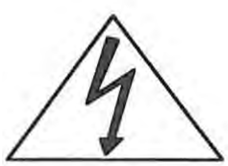
water is described later in this chapter in the section titled, "First Time Start-Up Procedure".



When working on or inspecting the main power supply power lines, turn off the facility circuit breaker and open the main fuse block on the power supply rear panel. Disconnect the power supply at the user supplied AC electrical connector.

Installing the Electrical Connector

The AC electrical connector must only be installed by a qualified individual in accordance with all applicable codes. The unterminated 4-wire main power cable from the power supply rear panel (Figure 4-2), contains brown, blue, black and yellow/green wires. Install your power connector onto this power cable. The yellow-green wire is earth ground. The brown, black and blue wires are incoming power lines that need to be connected to the three phases in the correct phase order. There is no neutral connection. The heat exchanger uses a three-phase motor, which will run in opposite direction if the incorrect phase order is used. The correct phase order is brown- blue- black. Incorrect phase orders are connections where the number of interchanged pair of wires is odd. The laser system will not turn on if the phase order is incorrect and the remote will display the fault: "Line Phase Order". In that case the power connector wiring needs to be corrected by swapping one pair of phase connections. The work should be performed by a qualified individual in accordance with all applicable codes.



Do not change any wiring inside the power supply or heat exchanger.

Connecting the Power Cable

Verify that the keyswitch is off, power supply main fuse block is open (located on power supply rear panel), and facility power circuit breaker is off. Connect the power supply cable to the facility power.

External Interlock

The Sabre ion laser is equipped with an external interlock connection located on the rear of the power supply (refer to Figure 5-9). When the system is shipped, this connection is jumpered. An external interlock circuit can be connected to the laser system and wired to, for example, a door switch to provide additional laser operating safety. When the door is opened, the laser will shut down.

For more information, refer to Chapter Five, System Description and Control, in the section titled, POWER SUPPLY COMPONENTS AND CONTROLS: External Interlock.

External Switch

The Sabre power supply is equipped with an externally accessible switch that closes when the laser tube becomes ionized. This provides a convenient way of having e.g. a safety light automatically switched on as the laser starts. The switch is located on the rear of the power supply (refer to Figure 5-9).

For more information, refer to Chapter Five, System Description and Control, in the section titled, POWER SUPPLY COMPONENTS AND CONTROLS: External Switch.

External Shutter Interlock

This interlock is connected to the external shutter in the laser head. As long as the circuit is closed, the external shutter can be opened and closed from the Remote Control Module through the system software (refer to Figure 5-10). If the circuit is opened, the external shutter will close overriding the software setting. This feature provides the user with a convenient way of having the laser light conditionally switched off without turning off the laser system in case a door into the laboratory is opened.

For more information, refer to Chapter Five, System Description and Control, in the section titled, LASER HEAD AND AUTOMATED FEATURES: External Shutter Interlock.

Before Turning On The Laser

First time system turn-on must only be performed by a Coherent service engineer. Follow the instructions below before turning on the system for the first time.

1. Remove covering material from output aperture on laser head front panel.

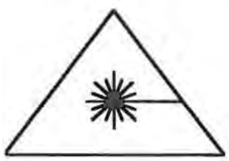
2. Read Chapter Five, System Description and Control; and Chapter Six, Daily Operation.

3. Perform the First Time Start-up procedure below.

First Time Start-Up Procedure

This procedure is intended for starting the laser for the first time after initial installation or after the laser has been moved. Refer to Chapter Nine, Troubleshooting, to resolve any faults or problems encountered.

Before continuing, it is recommended that Chapter Three, Laser Safety, is read and understood.



Ensure all personnel in the work area are wearing laser safety glasses appropriate for the wavelengths and power levels produced.

1. Turn off the facility circuit breaker.

3. Turn the keyswitch on the power supply to OFF.

4. Turn the switch on the heat exchanger to OFF.

4. Turn the intracavity shutter, located at the rear on the laser head, to CLOSED.

5. Place a power meter head or a beam stop in front of the laser output aperture to block the beam.

Priming The Heat Exchanger

The heat exchanger system needs to be filled with water and the pump primed with water before starting the system.

1. Fill the reservoir with clean tap water through the top access panel. Do not fill above the "MAX" fill line shown at the slot on the side of the heat exchanger main cover.

2. Turn on the facility primary cooling water to the heat exchanger. To avoid over pressurization of the cooling

system, open the drain valve before opening the supply valve. Check for water leaks.

3. Close the main fuse block on the power supply rear panel.

4. Turn on the facility circuit breaker.

5. Turn the keyswitch located on the power supply to ON and wait for the remote control module to power up. If a FAULT message does not appear on the remote module, proceed to step 6.

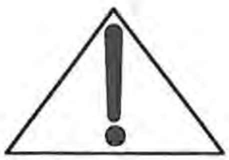
   If a FAULT message appears on the remote module, refer to Chapter Nine, Troubleshooting, to correct the fault before proceeding. A listing of possible fault messages is given in Table 9-2.

6. Manual control of the heat exchanger will be used to prime the heat exchanger pump with water. Make sure at this point that the switch on the front panel of the heat exchanger is in the OFF position. Manual control can be achieved through the remote module. The extended menus need to be available on the remote (Sabre Power Supply DIP switch 8 on MY TALK ADDRESS = ON). Navigate the menu tree as shown in Figure 4-4. See also Chapter Five, System Description and Operation for more information. Use the up/down arrows to select the "ON" parameter and press SELECT to turn on manual operation of the heat exchanger. The heat exchanger will not turn on at this point since the switch on the front panel of the heat exchanger is still in the OFF position. In this mode the heat exchanger can be turned on and off by the heat exchanger REMOTE/OFF switch.

7. Turn the switch on the front panel of the heat exchanger to the "REMOTE" position for a few seconds to start the pump. Watch the water in the reservoir during pump operation. The water level will drop and air bubbles will be created in the reservoir as soon as the pump starts filling the system with water. Turn off the heat exchanger as soon as the water level drops a few inches. The water level should always remain above the pump intake. Never run the pump dry for more than a few seconds.

   Check that there are no water leaks in the laser head or in the heat exchanger. If a leak is detected, set the switch on the heat exchanger to the OFF position immediately.

8. Refill the reservoir to the indicated fill range again and repeat step 7. Repeat this procedure until the water level does not change any more. The water level should be within the "MIN" to "MAX" range, as shown by the label on the side of the heat exchanger main cover, with the pump running and the system de-ionized.



Do not overfill the heat exchanger reservoir. Filling above the "MAX" fill line can create water overflow while the system is running because the water expands while warming up.

9. Replace the fill cap of the heat exchanger reservoir and close the cover. The heat exchanger is ready for operation. When the system is ionized, ensure that the water flow rate and inlet water temperature are properly set at their nominal values. Refer to Chaper Five, System Description and Controls, in the appropriate section and subsections titled, SABRE HEAT EXCHANGER.

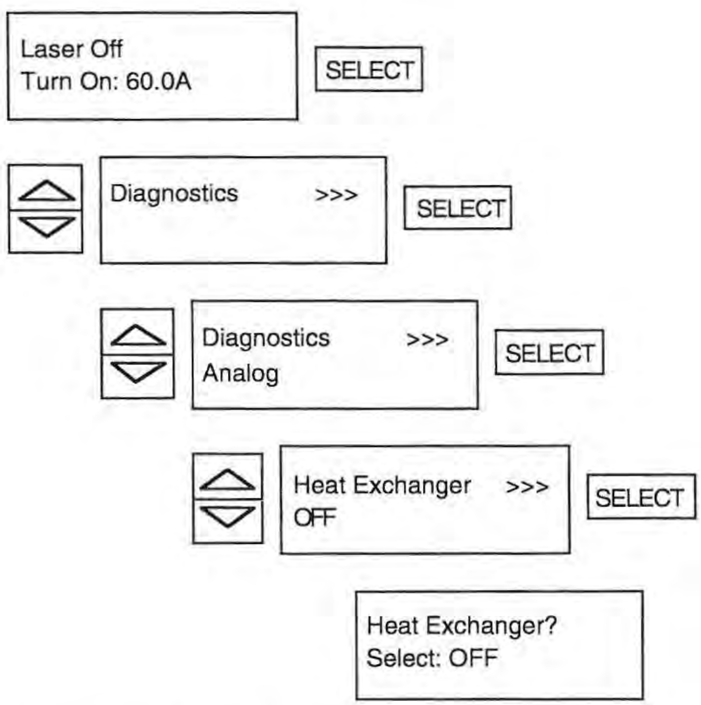
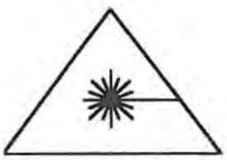


Figure 4-4. Manual Heat Exchanger Control

Ionizing The Laser

The optical surfaces need to be inspected for dirt before using Sabre to prevent damage to the optics. If any dirt particles fell on the optical surfaces during shipment these surfaces could be burned by the high intracavity power at high tube current. Refer to Chapter Seven, Optics and Alignment Procedures, in the section titled: CARE AND CLEANING OF OPTICS for inspection and cleaning procedures. Use low tube current during these procedures to prevent damage to the optics. If any system fault messages are displayed by the remote, refer to Chapter Nine, Troubleshooting.



Safety glasses or goggles, which protect against the wavelengths used, should be worn at all times during these procedures.

1. Press the ON button on the remote control module to initiate the start delay cycle.
   - The remote control module will read `START DELAY` and a 75 second count down will be initiated.
   - The heat exchanger will reset to automatic mode turn on.
   - White LASER EMISSION indicators on the front of the laser head and on the remote control module will light.
   - With 50 seconds remaining of the start delay count down, the main contact inside the power supply will engage. The contact makes a distinctive sound which easily can be heard except in unusually noisy environments.
   - When the start delay count down is completed, the plasma tube will ionize and conduct current.
2. Open the intracavity shutter.
3. The laser might be misaligned from shipment to the point of no lasing. Lasing can be obtained by pressing the TUNE button.
4. Verify that system output power is equal to or greater than the power specification . Refer to Chapter Two, System Specifications and Parameters. If the system provides the required output power and is stable, it is ready for operation. Otherwise, refer to Chapter Nine, Troubleshooting, to isolate causes of low or unstable output power.

Operator's Manual

Chapter Five
System Description and Control

COHERENT

Introduction

This chapter describes the components and system control of the Sabre ion laser.

REMOTE BASICS describes a general overview of the basic functions and operation of the remote control module.

SABRE HEAT EXCHANGER describes the features and controls of the heat exchanger unit.

POWER SUPPLY COMPONENTS AND CONTROLS lists and details controls on the power supply.

LASER HEAD AND AUTOMATED FEATURES describes the laser head, its automatic features, and how these are used to optimize the laser operation.

REMOTE CONTROL MODULE, REMOTE STANDARD MENUS, and REMOTE EXTENDED MENUS are reference sections that describe how the remote control module is utilized to control laser operation through the CPU and describe each menu element.

CURRENT REGULATION MODE and LIGHT REGULATION MODE describe in detail the system regulation modes.

AUTOFILL describes the autofill system and its implication towards system operation.

Remote Basics

Information is organized in a menu tree. The menu tree consists of several menu levels that branch out from high to low. There may be one or more members within each menu level. The "Default Menu" that appears when the keyswitch is first turned ON is a member of the highest menu level. Subsequent menu levels display >>> in the upper right corner if a lower menu level exists.

Navigating Menu Trees

SELECT: Move to a lower menu level.

EXIT: Move to a higher menu level.

Up/Down Arrows: Scroll members of a given menu level.

Selecting Operating Parameters Within Lower Menu Levels

Navigate to desired lower menu level. Any parameter after the word "Select:" is variable. Use Up/Down Arrows to display desired value. Press Select to enter value.

The remote is capable of displaying a standard set and an extended set of menus. To enable access to the extended menus, set switch 8 on the MY TALK ADDRESS DIP switch on the rear panel of the Sabre power supply to the up (ON) position.

Figure 5-1. Sabre Remote Control Module

Table 5-1. Basic System Operation

ON/OFF	Initiate sequence to ionize plasma tube. Turn on heat exchanger. De-ionize plasma tube. Illuminated LASER EMISSION lamp indicates On.
LIGHT	Select Light Regulation Mode (constant optical power) or Current Regulation Mode (constant tube current). Steady on LED indicates Light Regulation Mode. A flashing LED indicates that the system is unable to achieve the light regulation setpoint and light regulation is non-operational. Possible causes may be that the system is not lasing or the setpoint is too high.
Up/down arrows	Scroll setpoint for light or current regulation. Select memory levels in memory mode of operation.
MEMORY	Activate or de-activate memory mode of operation. Illuminated LED indicates memory mode of operation active. Up selects memory level 1 system operating parameters and Down selects memory level 2 parameters.
TUNE	Close external shutter. Center front mirror in adjustment range. Peak up system with rear mirror. If system is not lasing, system goes to maximum current with open aperture. Rear mirror searches for lasing and peaks up system. To abort, press Exit.
SHUTTER	Open or close external shutter. Illuminated LED indicates open shutter.
PWR TRK	Turns PowerTrack on or off. Steady on LED indicates PowerTrack operating. A flashing LED indicates that PowerTrack is at its limit and non-operational. Press TUNE to re-peak the system.

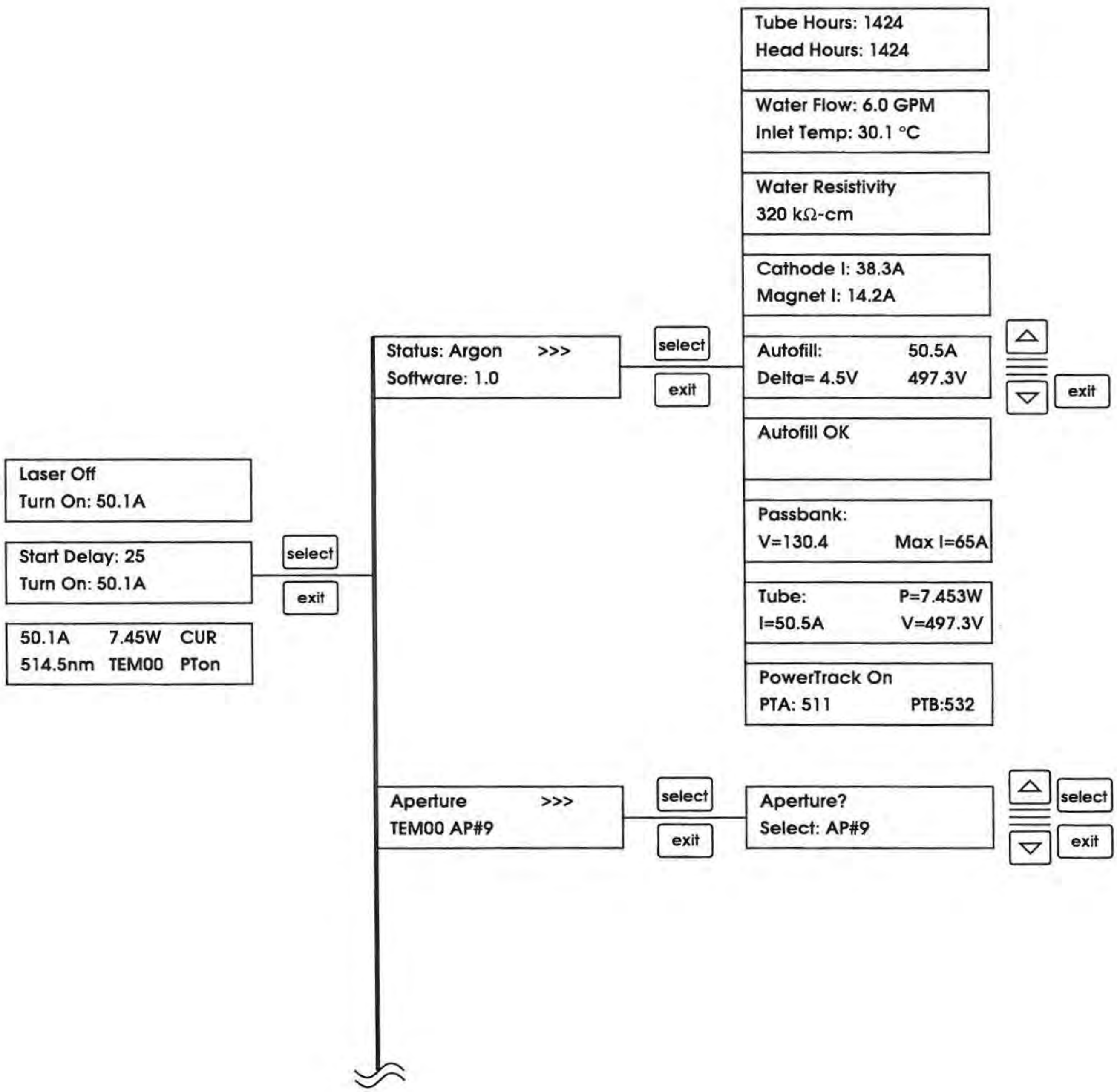


Figure 5-2a. Sabre Menu Tree, Standard Menus (Sheet 1 of 5)

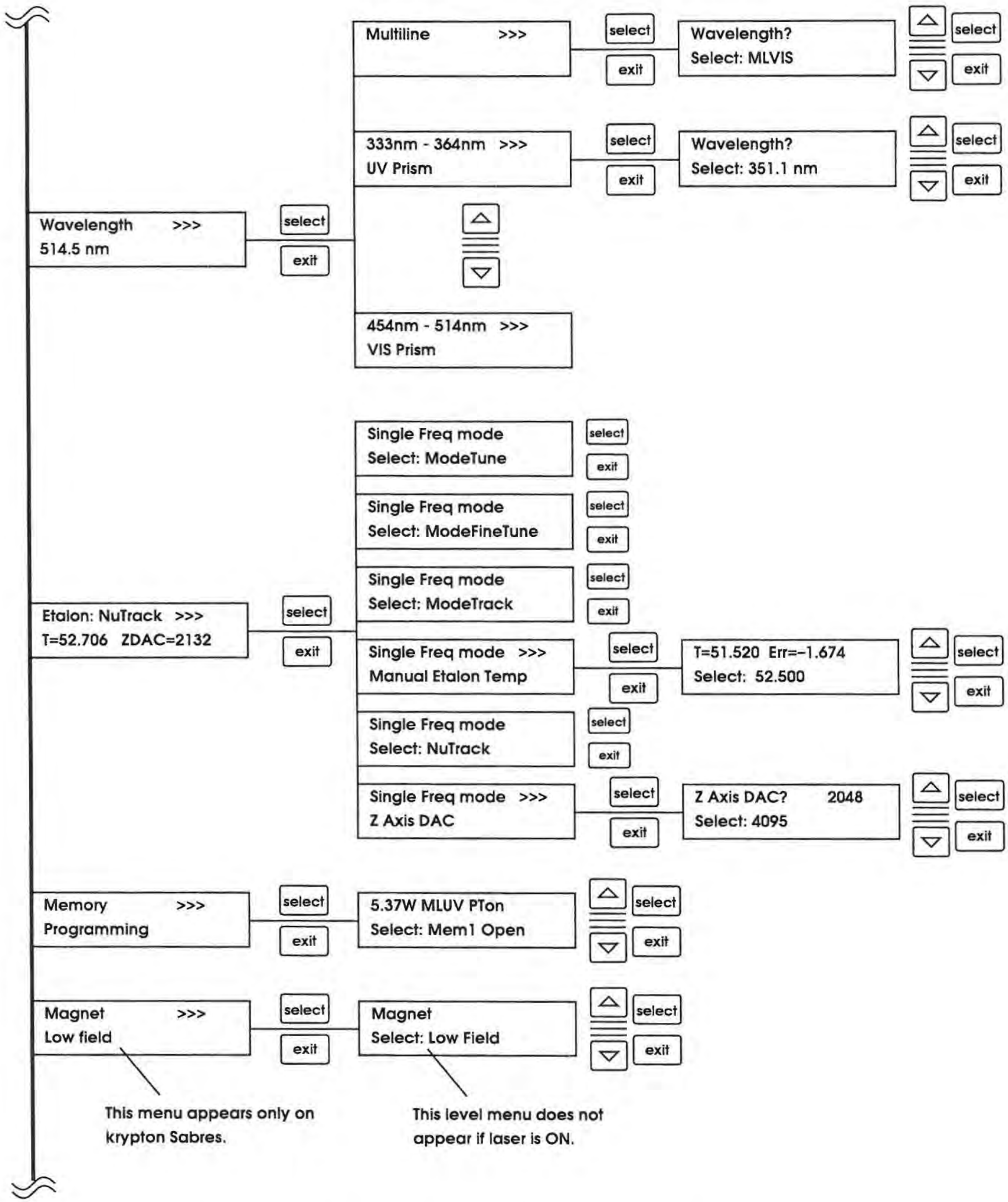


Figure 5-2a. Sabre Menu Tree, Standard Menus (Sheet 2 of 5)

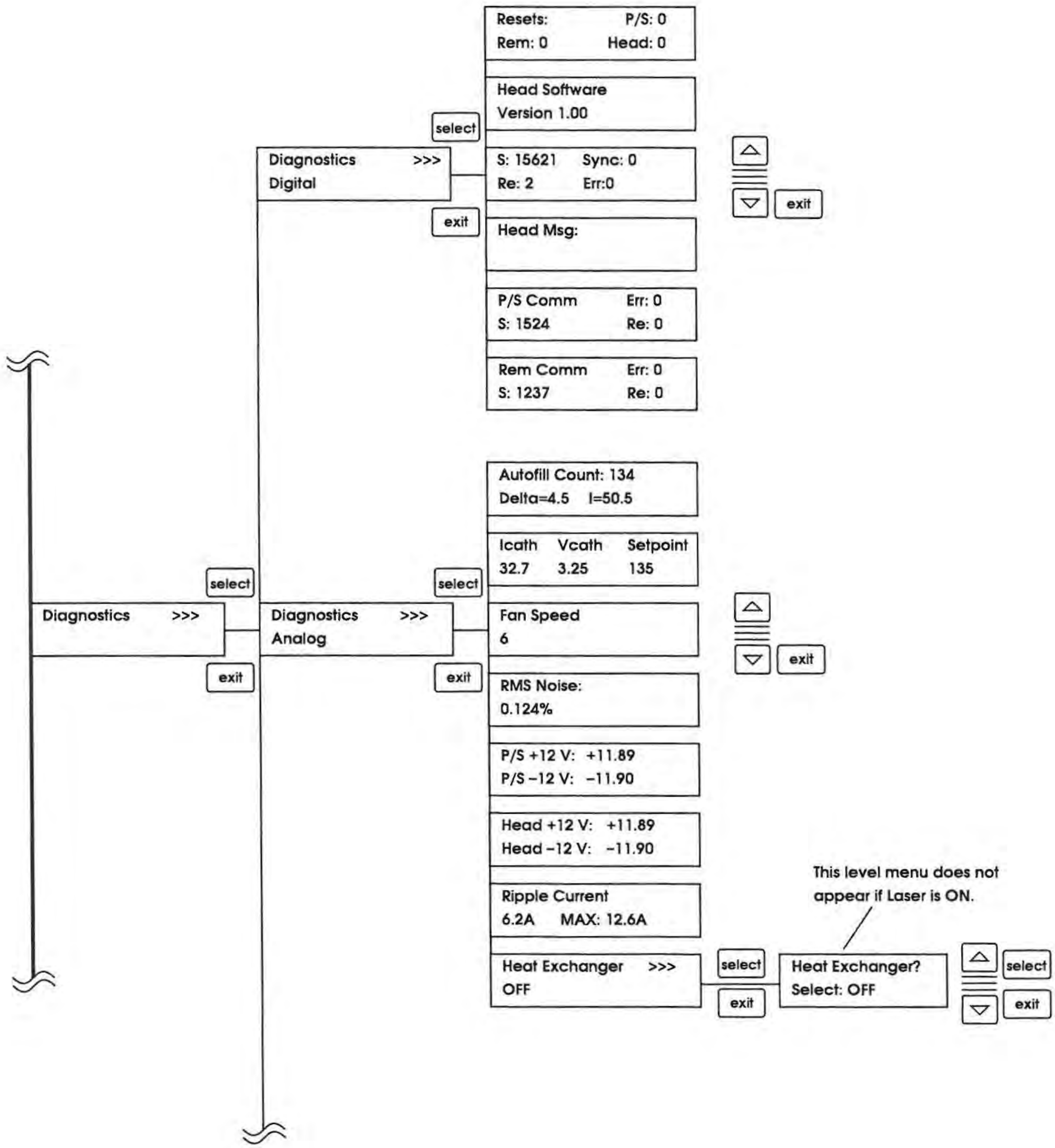


Figure 5-2b. Sabre Menu Tree, Extended Menus (Sheet 3 of 5)

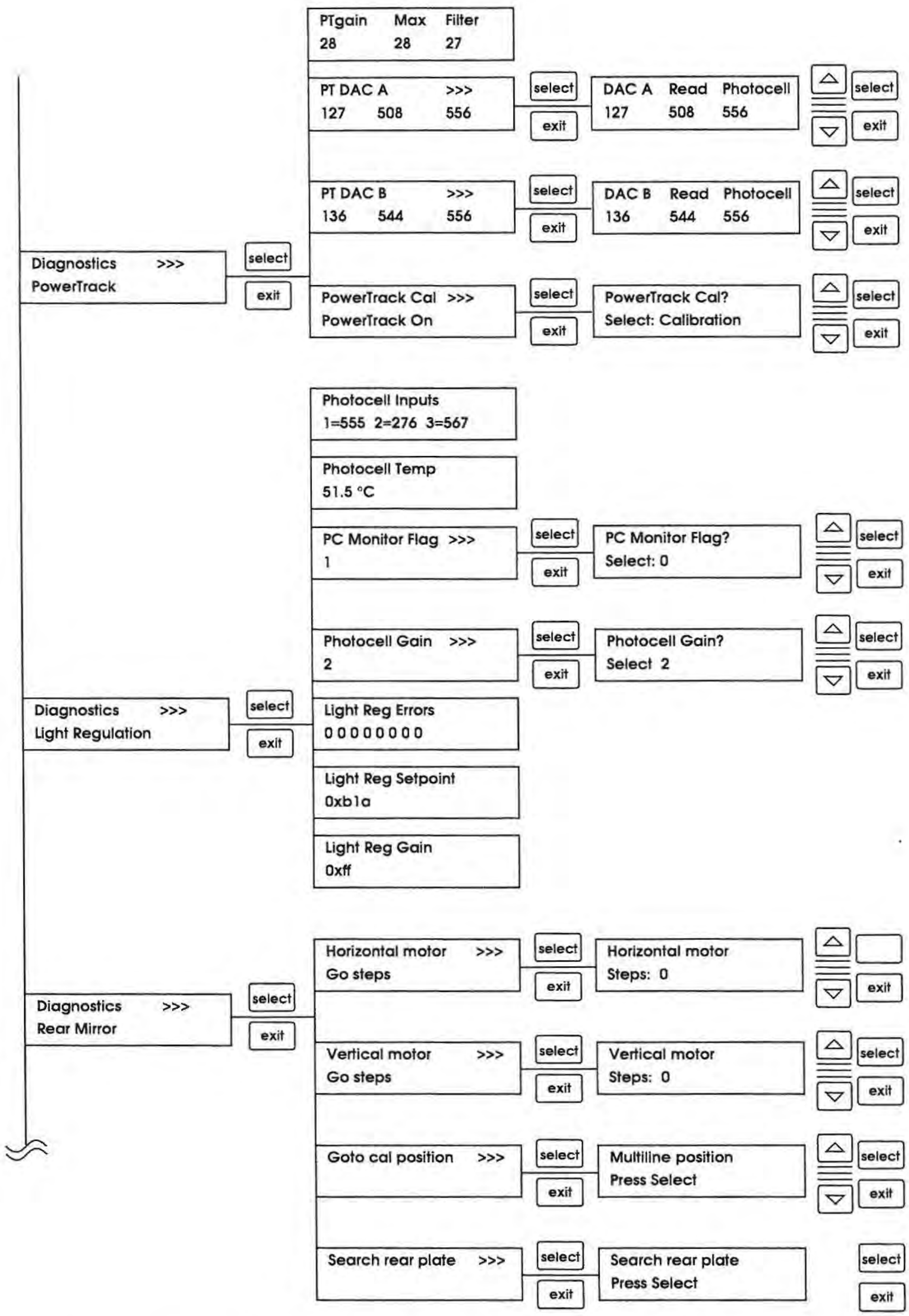


Figure 5-2b. Sabre Menu Tree, Extended Menus (Sheet 4 of 5)

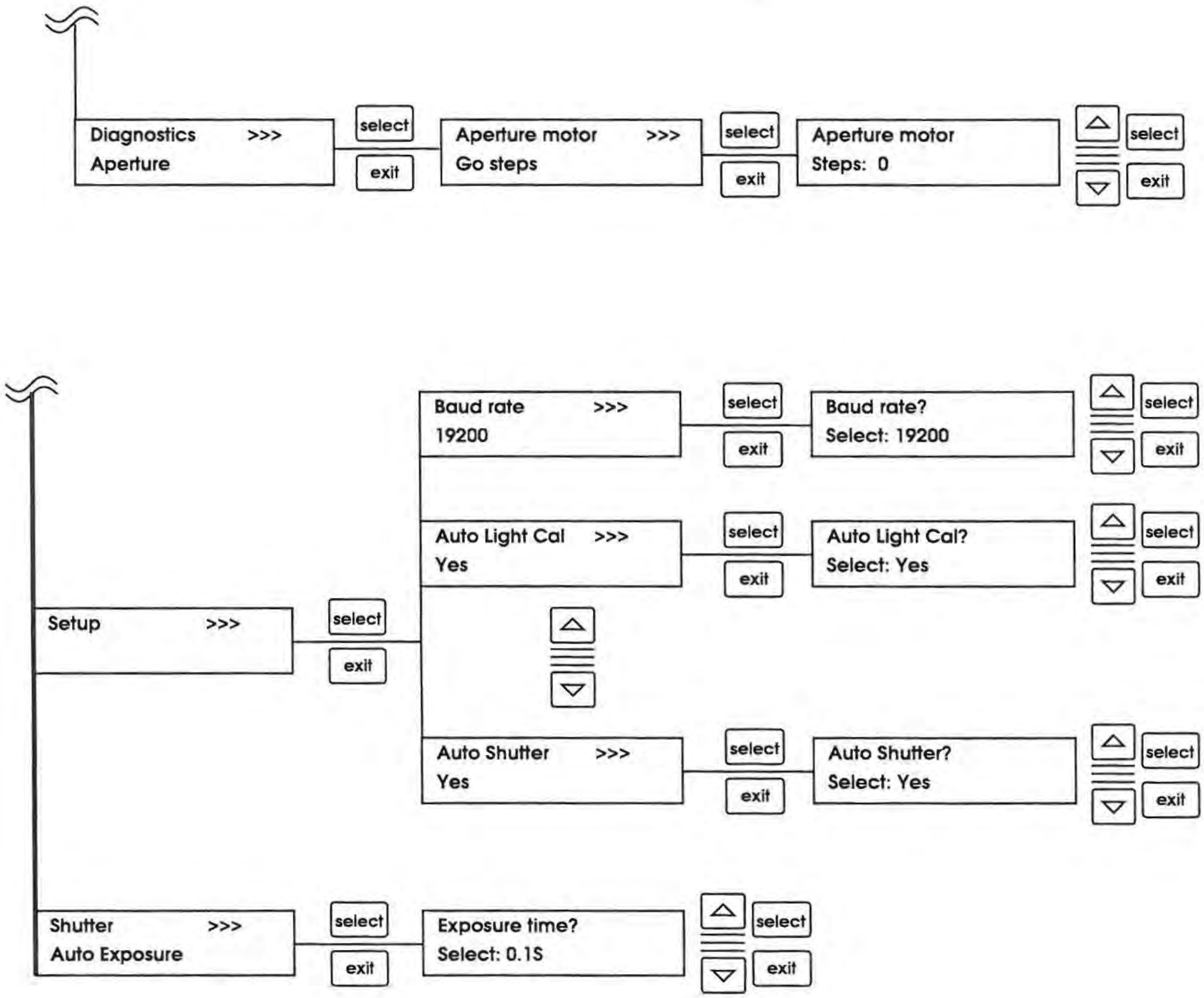


Figure 5-2b. Sabre Menu Tree, Extended Menus (Sheet 5 of 5)

Sabre Heat Exchanger

The Sabre ion laser utilizes the heat exchanger to provide its cooling water needs. The water-to-water heat exchanger conducts heat produced by the laser system in a secondary closed loop to a primary water supply provided by the facility site. The secondary closed loop that circulates through the laser system is temperature and flow regulated and filtered. The result is a clean, stable source of cooling water that extends the plasma tube's useful life and provides for stable system operation.

The Sabre heat exchanger is shown schematically in Figure 5-3. The hot water returning from the power supply enters the plate heat exchanger core where the excess heat is transmitted to the house (facility) water. The Temperature Regulation Valve regulates the house water flow to maintain a set water temperature, measured in the reservoir, of the secondary closed loop. Water is stored in the reservoir to ensure sufficient volume of water that may be lost as a result of evaporation and to increase the thermal capacity of the secondary loop. The water level in the reservoir is measured by a sensor to warn the user of a low level through a system recognized fault.

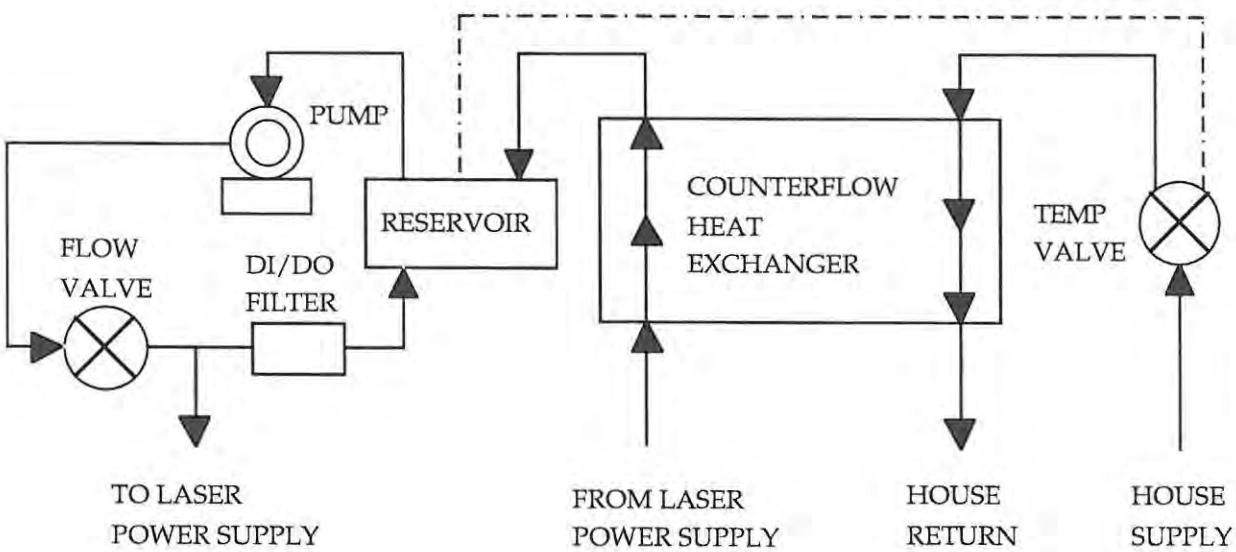


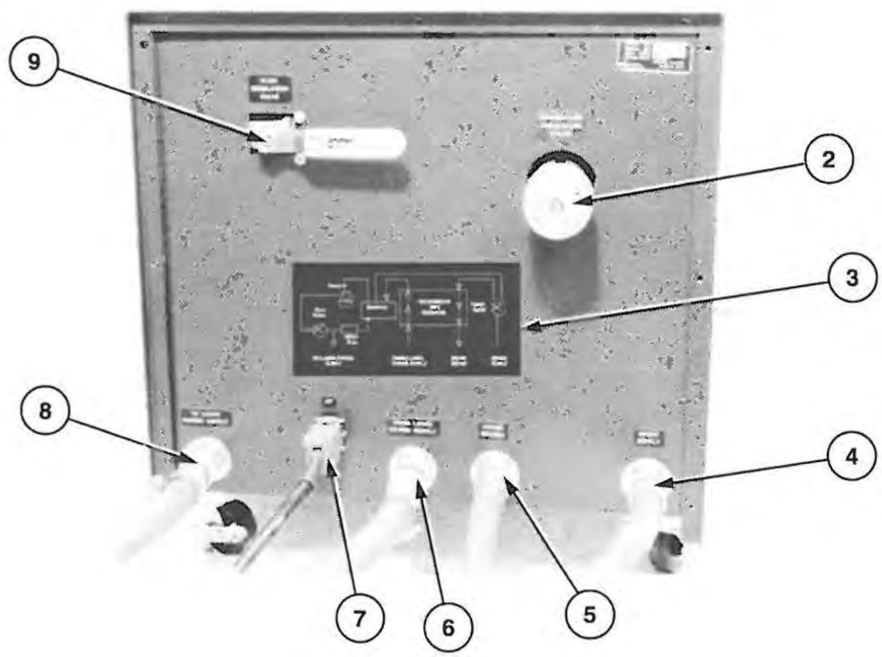
Figure 5-3. Schematic of Heat Exchanger

Water is drawn from the resivoir by the pump and passed through the Flow Regulation Valve on its way to the laser power supply. A small amount of water is diverted from the output flow and passed through a de-ionizing/de-oxygenating (DI/DO) filter cartridge to maintain a reasonable value of the water resistivity.

The Sabre heat exchanger is powered by and automatically turned on and off by the Sabre power supply in normal operating conditions. The heat exchanger is automatically turned on when the ON button is pressed on the remote to initiate the start delay sequence for ionization or when a request to turn the system on is issued through external computer control (Command: Laser = 1). When the start delay sequence is interrupted or the system is de-ionized by pressing the OFF button on the remote or through external computer control (Command: Laser = 0), the heat exchanger continues to circulate cooling water for a set time period, 5 minutes, to allow for a proper cool down of the plasma tube and magnet. It is important to maintain facility power after the system is shut down until completion of this cool down period to eliminate possible damage to the plasma tube and/or magnet.

A slot in the side of the heat exchanger main cover provides visibility of the water level in the reservoir. To fill the reservoir, the reservoir top cover is accessible through a small subcover on the top of the heat exchanger main cover. The water level should be maintained within the range shown on the main cover label when the system is de-ionized and cold. If the level is too low, the pump may not function properly and may circulate air bubbles through the system which could result in damage to the plasma tube and/or magnet. If the level is too high, leaks may result as the water expands and may provide conditions allowing for the possible risk of an electrical malfunction. If the reservoir level drops below a certain value, the system fault message "H/E Low Reservoir" will be displayed on the remote or will be accessible through external computer control (Query: Print Faults). For more information, refer to Chapter Nine, Troubleshooting.

Procedures for the initial installation and operation of the heat exchanger are described in Chapter Four, Utility Requirements and System Installation.



1. Remote/Off switch
2. Temperature Regulation Valve
3. Schematic diagram; heat exchanger
4. Primary inlet water hose connector - from facility
5. Primary outlet water hose connector - return to facility
6. Secondary inlet water hose connector - from power supply
7. Power cable from power supply
8. Secondary outlet water hose connector - to power supply
9. Flow Regulation Valve
10. Locking wheels

Figure 5-4. Sabre Heat Exchanger Front and Rear Views

Remote/Off Switch

A control switch, with two positions labeled "REMOTE" and "OFF", is located on the front of the Sabre heat exchanger (see Figure 5-4). In normal operating conditions, the switch must remain in the "REMOTE" position. This permits the Sabre power supply to maintain control of the power to the pump motor in the heat exchanger. Setting the switch to the "OFF" position disables this control and cuts power to the pump motor. Note: Do not use the "OFF" switch position as an emergency system shut off because severe or irreparable damage to the plasma tube and/or magnet may result if the flow of cooling water to an ionized system is interrupted. The "OFF" position should only be used in special situations in conjunction with manual heat exchanger control as described below.

Manual Heat Exchanger Control

Manual control of the Sabre heat exchanger may be exercised in special situations, such as leak testing during initial installation. The heat exchanger may be turned on through the remote or through external computer control (Command: Water = 1) without initiating the start delay sequence to ionize the plasma tube. The pump will run indefinitely while the manual heat exchanger control is set to ON and the system is de-ionized. When the system is requested to turn on and initiate the start delay sequence, manual heat exchanger control is canceled and automatic control by the Sabre power supply is initiated.

To manually turn on the heat exchanger without system ionization from the remote module requires the extended menus to be displayed on the remote (Sabre Power Supply DIP switch 8 on MY TALK ADDRESS = ON). Navigate the menu tree as shown in Figure 5-5. Use the up/down arrows to select the "ON" parameter and press SELECT to turn on the heat exchanger. The lowest menu level shown in Figure 5-5 only exists when the system is de-ionized.

The status of the manual heat exchanger control can be checked through inspection of "Heat Exchanger OFF (or ON)" menu shown in Figure 5-5 or through external computer control (Query: Print Water). This parameter is always set to "ON" while the system is in start delay or ionized.

To turn off the manual heat exchanger control from the remote, follow the menu path shown in Figure 5-5. Use the up/down arrows to select the "OFF" parameter and press SELECT to turn off manual control. Alternatively, use external computer control (Command: Water = 0).

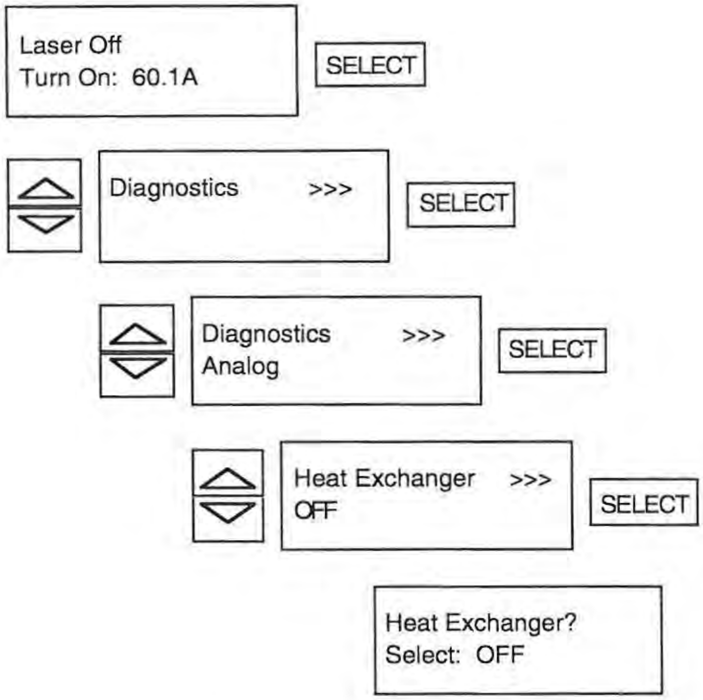


Figure 5-5. Heat Exchanger Manual Control Menu Path

In either case, when manual heat exchanger control is set to OFF, the heat exchanger will continue to circulate water for its set cool down time period, 5 minutes, before turning off the pump.

If the manual heat exchanger control has been set to ON in special situations, such as leak testing during initial installation, and an immediate shut down is required due to a leak, use the "OFF" position of the control switch on the front of the heat exchanger. Caution must be exercised subsequently because returning the switch to the "REMOTE" position will resume power to the pump motor. To prevent this occurrence, set the manual heat exchanger control to "OFF", using the procedures described above, before assuming the "REMOTE" position of the switch. To cancel the 5 minute cool down timer, shut off main facility power.

Controlling and Monitoring Flow Rate

The flow rate of the water circulating in the secondary loop through the laser can be controlled using the Flow Regulation Valve located on the rear of the Sabre heat exchanger (refer to Figure 5-4). When the orientation of handle is horizontal, the valve will be fully open. When the orientation of the handle is vertical, the valve will be closed. The flow rate should be

adjusted and set to be in the range of 6 to 8 gallons per minute (22.7 to 30.3 liters per minute). A recommended nominal value of flow rate is 6 gallons per minute (22.7 liters per minute).

The flow rate can be monitored through the remote or external computer control (Query: Print Water Flow or Print Flow). To determine the water flow rate through the remote, navigate the menu tree as shown in Figure 5-6. Monitoring of the flow rate can also be useful in determining when the heat exchanger has shut down after its cool down period. If the flow rate drops below a certain value (when the heat exchanger is set to ON), the system fault message "Low Water Flow" will be displayed on the remote or will be accessible through external computer control (Query: Print Faults). For more information, refer to Chapter Nine, Troubleshooting.

Controlling and Monitoring Inlet Water Temperature

The temperature of the water in the secondary closed loop can be controlled using the Temperature Regulation Valve located on the rear of the Sabre heat exchanger (refer to Figure 5-4). Rotation of the valve in a clockwise direction will result in cooler water temperature for the secondary closed loop entering the Sabre power supply. In general, clockwise rotation of the valve will also require a higher rate of the house or facility water flow. When the valve is fully opened in the clockwise direction, the valve will no longer regulate the temperature of the secondary closed loop and maximum facility water flow rate will ensue. This position is useful when draining the house side of the heat exchanger for transport or storage.

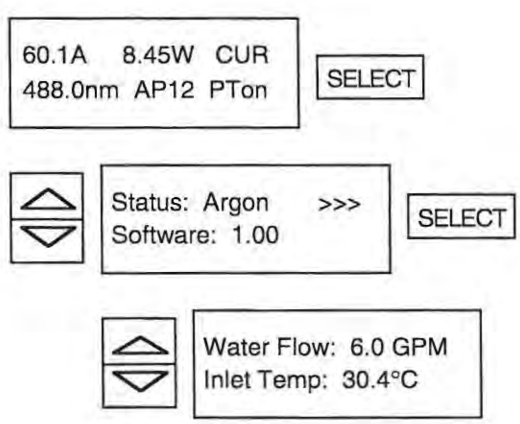


Figure 5-6. Water Flow Rate and Inlet Temperature Menu Path

The power supply inlet water temperature is measured within the Sabre power supply and can be monitored through the remote or external computer control (Queries: Print Water Temperature). To determine the water inlet temperature from the remote, navigate the menu tree as shown in Figure 5-6. If the inlet temperature is not within a specified range (when the heat exchanger is set to ON), the system fault message "Inlet Water Temp" will be displayed on the remote or will be accessible through external computer control (Query: Print Faults). For more information, refer to Chapter Nine, Troubleshooting.

Adjustment of the Temperature Regulation Valve should only be made when the system is ionized and warmed-up. When the valve is then adjusted, there will be a certain amount of overshoot in response to the adjustment. It will be required to monitor the power supply inlet temperature for several minutes until the temperature stabilizes after each adjustment. The inlet water temperature should be maintained in the range of 20 to 35 °C (68 to 95 °F) and is nominally set at the factory to 30 °C (86 °F) as shown by the label on the valve stem.

If the Temperature Regulation Valve is set in a nominal position that would regulate the secondary loop at a given temperature and the system produces little or no heat, then the Temperature Regulation Valve will automatically close and impede house or facility water flow. This situation is normal and explains why facility water flow is zero when the system first is turned on or near the end of its cool down period or when the heat exchanger is run in manual mode with the system off and cool.

Monitoring Water Resistivity

The Sabre heat exchanger incorporates a de-ionizing/ de-oxygenating (DI/DO) filter cartridge to maintain a reasonable value of the water resistivity. A moderately high water resistivity prevents corrosion and scale build-up within the secondary closed loop.

The water resistivity is measured within the Sabre power supply and can be monitored through the remote or external computer control (Query: Print Water Resistivity). To determine the water resistivity from the remote, navigate the menu tree as shown in Figure 5-7. The value of the water resistivity should exceed 100 kΩ-cm.

If the water resistivity drops below 100 kΩ-cm, the system warning message indicating low water resistivity, as shown in Figure 5-8, will be displayed on the remote irregardless of

the current menu level. A new DI/DO cartridge should be ordered and installed

To clear the warning message from the remote display, use the EXIT or SELECT buttons. It is recommended to use the EXIT button when displaying lower menu levels to avoid inadvertently selecting an undesirable system operating parameter. Use the SELECT button when displaying the "Default Menu". This warning message is not available through external computer control. The reported value of the water resistivity should be periodically monitored (Query: Print Water Resistivity).

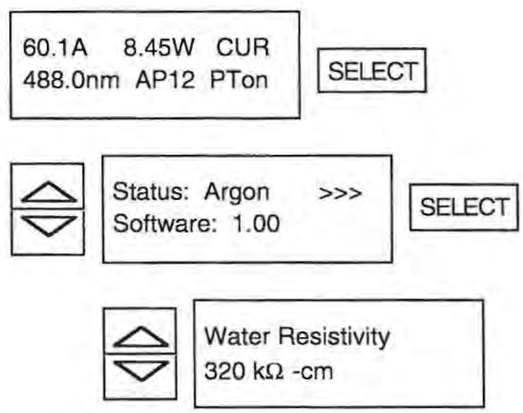


Figure 5-7. Water Resistivity Menu Path

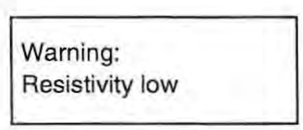


Figure 5-8. Low Water Resistivity Warning Menu Display

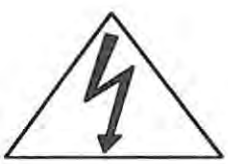
Power Supply Components and Controls

There are few controls on the power supply. The master ON/OFF keyswitch and two indicator LEDs are located on the front panel. A set of DIP switches, labeled "MY TALK ADDRESS", is situated on the rear panel. The rear panel contains the main fuse block and connection ports for the remote, heat exchanger, the laser head umbilical, and an external interlock. Procedures for connecting the laser head umbilical, remote control module, external interlock, facility

AC power, and heat exchanger are given in Chapter 4, Utility Requirements and System Installation. The external computer control ports located on the rear of the power supply, the standard RS-232/422 interface and the optional IEEE-488 interface, are described in Chapter Eleven, External Computer Control.

Keyswitch

The system keyswitch is located on the front panel of the power supply (refer to Figure 5-9). In the ON position, the power supply and CPUs are activated providing full system control through the remote control module or computer interface. All system status indicators and interlocks are activated and the power supply fans will be on. As long as the keyswitch is ON, the photocell and etalon remain thermally stabilized. Power consumption of the Sabre power supply when the system is de-ionized is less than 150 W.



High voltage is present in the power supply, even with the keyswitch in the OFF position.

In the OFF position, the power supply is deactivated rendering laser operation impossible. If the Sabre heat exchanger had been operating when the keyswitch was turned OFF, the heat exchanger will continue to operate until completion of its 5 minute cool down period.

Although not recommended, the keyswitch may also be used to de-ionize and shut down the system in rare emergency situations where the remote or external computer control are non-responsive. This is the preferred choice in such rare situations because the interruption of main facility power will shut down the heat exchanger, suspending the circulation of system cooling water which could severely damage the plasma tube and/or magnet.

Indicator Lights

There are two LED indicators located on the front of the power supply, shown in Figure 5-9, which will illuminate whenever the system keyswitch is in the ON position. When lit, the upper LED indicates proper operation of the following internal voltage supplies: 24 V, ±12 V, and 5 V. The lower LED indicates proper operation of the power supply CPU. These LEDs should be illuminated whenever the system keyswitch is in the ON position. If either LED is out, suspect a fault and refer to Chapter Nine, Troubleshooting.

MY TALK ADDRESS DIP Switches

A small dip switch panel is located on the rear panel of the Sabre power supply labeled MY TALK ADDRESS (refer to Figure 5-9). If the system is connected to an IEEE-488 computer interface bus, switches 1 through 5 determine the laser's talk address (refer to Chapter Eleven, External Computer Control). Switch 8 determines the number of menus available on the remote control module. In the down (OFF) position, only the standard menus are accessible. In the up (ON) position, the extended menus will be accessible. Switches 6 and 7 have no function at the time of publication of this document.

Main Fuse Block

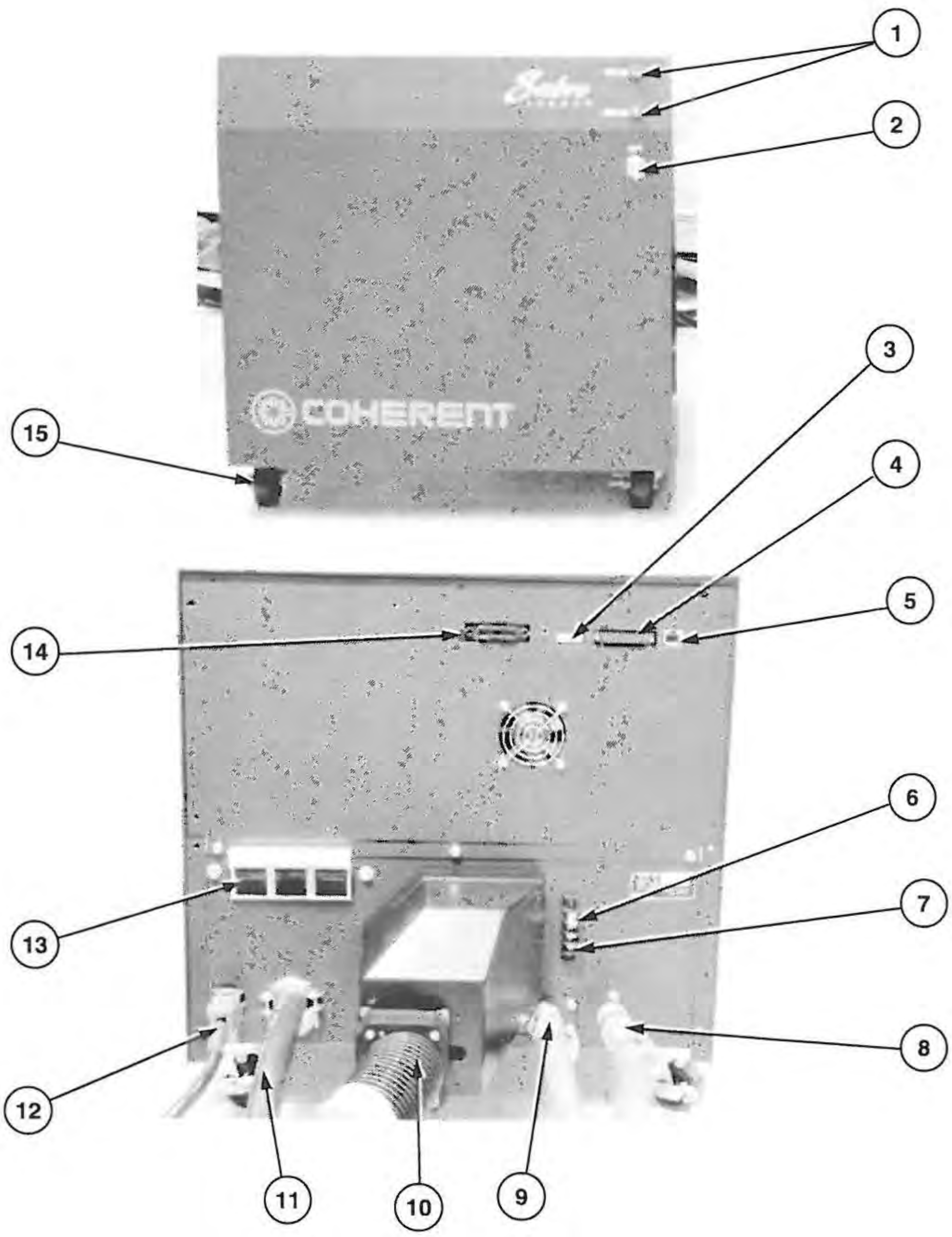
The main fuse block on the rear panel of the Sabre power supply, shown in Figure 5-9, controls application of facility power to the Sabre and also contains the three 80 A main line fuses. Note the high voltage is present in the power supply even when this fuse block is open and the keyswitch is in the OFF position.

External Interlock

The external interlock is located on the rear panel of the Sabre power supply, as shown in Figure 5-9. The top two terminals, 1 and 2, of terminal strip must be connected for the laser to operate. The factory installed jumper may be replaced with an external interlock circuit.

The External Interlock circuit may be wired to a door switch to shut off the laser when a person enters a designated restricted area.

The external interlock has an open circuit voltage of 20 to 28 VDC and a short circuit current of ≤ 12.0 mA. Under no circumstances should an external voltage or current source be connected to this circuit.



1. Indicator LEDs
2. Keyswitch
3. MYTALK ADDRESS DIP switch
4. RS-232/422 interface
5. Remote control module connector
6. External interlock
7. External switch
8. Secondary inlet water hose connector (from heat exchanger)
9. Secondary outlet water hose connector (to heat exchanger)
10. Laser head umbilical
11. Main power cable
12. Power cable to heat exchanger
13. Main fuse block
14. Optional IEEE-488 interface
15. Locking wheels

Figure 5-9. Sabre Power Supply: Front and Rear Views

If the external resistance connected between the terminals is less than 10 Ω, the laser is functional and will operate from the remote or external computer control. If the resistance is greater than 100,000 Ω, the laser is disabled and will not operate. To assure proper functioning of your laser system, design your external interlock circuit to have a resistance less than 10 Ω when closed and a resistance greater than 100,000 Ω when open. External interlock circuitry should be isolated from all other electrical circuits or grounds.

If the external interlock is open (jumper not installed or restricted area door open), the laser will not operate. The remote control module display will read: External Interlock.

External Switch

The external switch is located on the rear panel of the Sabre power supply, as shown on Figure 5-9. The bottom two terminals, 3 and 4, of the terminal strip function as a switch when the power supply main contactor is closed. (The main contactor closes 50 seconds before ionization and remains closed until the plasma tube is de-ionized.) The external switch may be used, for example, to turn on warning lights outside of the lab indicating that the system is ionized and possibly lasing.

This switch is isolated from all other laser circuits. It is rated for 600 VAC, 12 Amps (maximum). It is not internally protected by fuses or other overcurrent protection devices.

Laser Head and Automated Features

This section describes the Sabre laser head and outlines methods to control and monitor its automated features through the remote control module or external computer control. The automated features described here include the motorized rear mirror plate, the automatic aperture, the TEM_{00} detector, the external shutter, and the PowerTrack alignment servo.

The Sabre is designed to be essentially a hands-off system with most system control being accessible through the remote or external computer control. Therefore, there are very few manually adjustable controls on the Sabre laser head.

The Laser Emission Indicator on the front bezel (refer to Figure 5-10) is used to indicate the potential for laser emission from the Sabre head. When the keyswitch is ON and the system is requested to initiate the start delay sequence to ionize the plasma tube, the emission lamp will be illuminated

to warn that the tube will soon ionize. This indicator will remain illuminated while the system is ionized. It will be turned off when the system is shut down.

The vertical and horizontal output coupler mirror plate adjusts are used to change the tilt of front mirror plate (refer to Figure 5-10). Typical daily operation does not require use of these adjustments. Procedures requiring these adjustments will be outlined in Chapter Seven, Optics and Alignment Procedures.

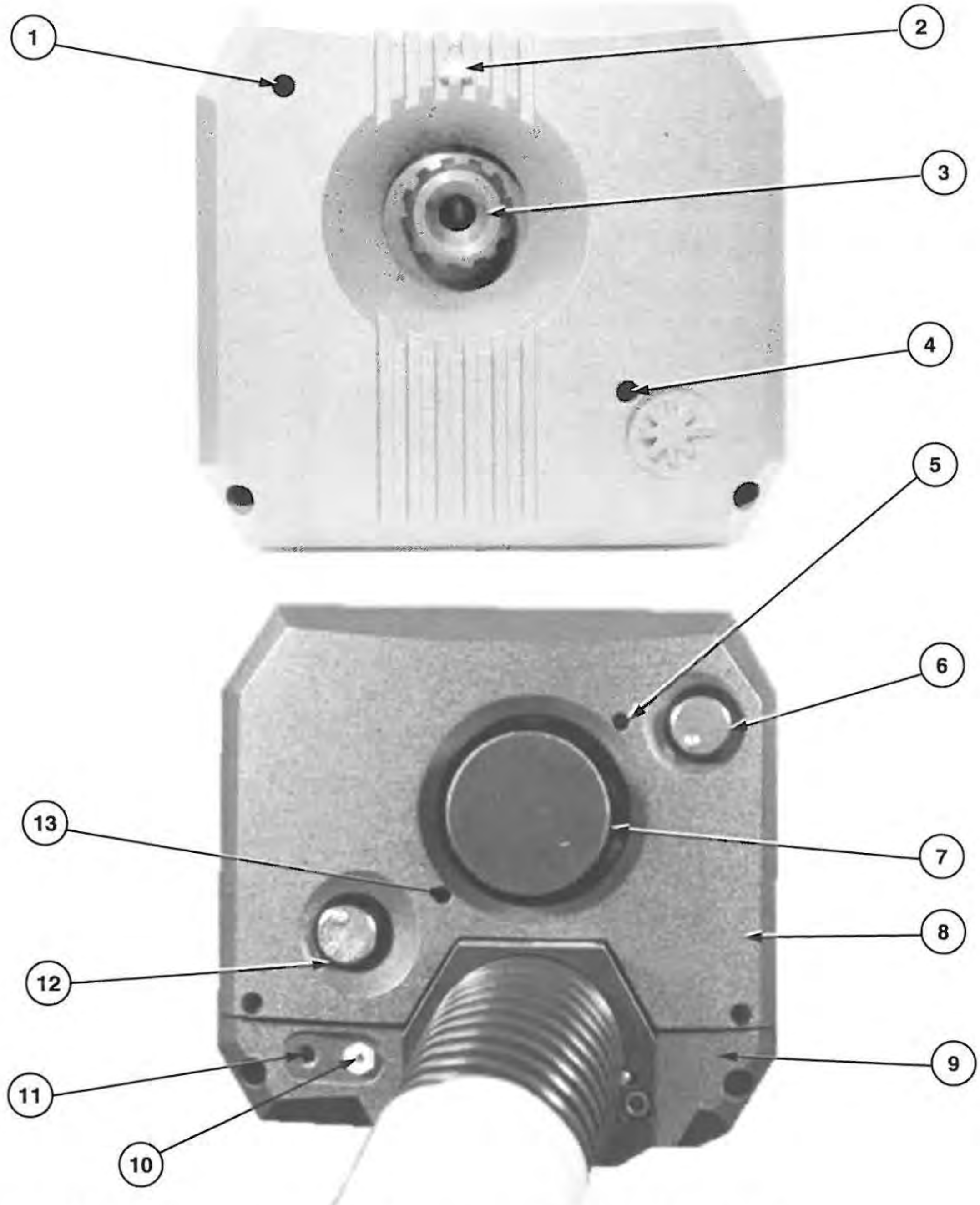
The rear bezel of the Sabre head is split into a fixed lower portion and a removable upper portion (refer to Figure 5-10). Use of the vertical and horizontal etalon adjusts is described in Chapter Eight, Single-Frequency Operation.

The high reflector will be contained in either the Multiline Mirror Holder or the Single Line Mirror Holder located as shown in Figure 5-10. Each mirror holder may be installed or removed by a slight rotation of the entire mirror holder assembly.

The vertical and horizontal high reflector fine adjusts should not be used in typical daily operation (refer to Figure 5-10). They are provided for qualified service personnel only. Rotation of either of these adjustments can undermine the system's ability to provide a properly functioning motorized rear mirror plate. The intracavity shutter, shown in Figure 5-11, is provided to stop lasing action when in the CLOSED position by interrupting the beam. The plasma glow of the tube will still exit the output coupler when the intracavity shutter is closed. The intracavity shutter should must be in the OPEN position to enable lasing.

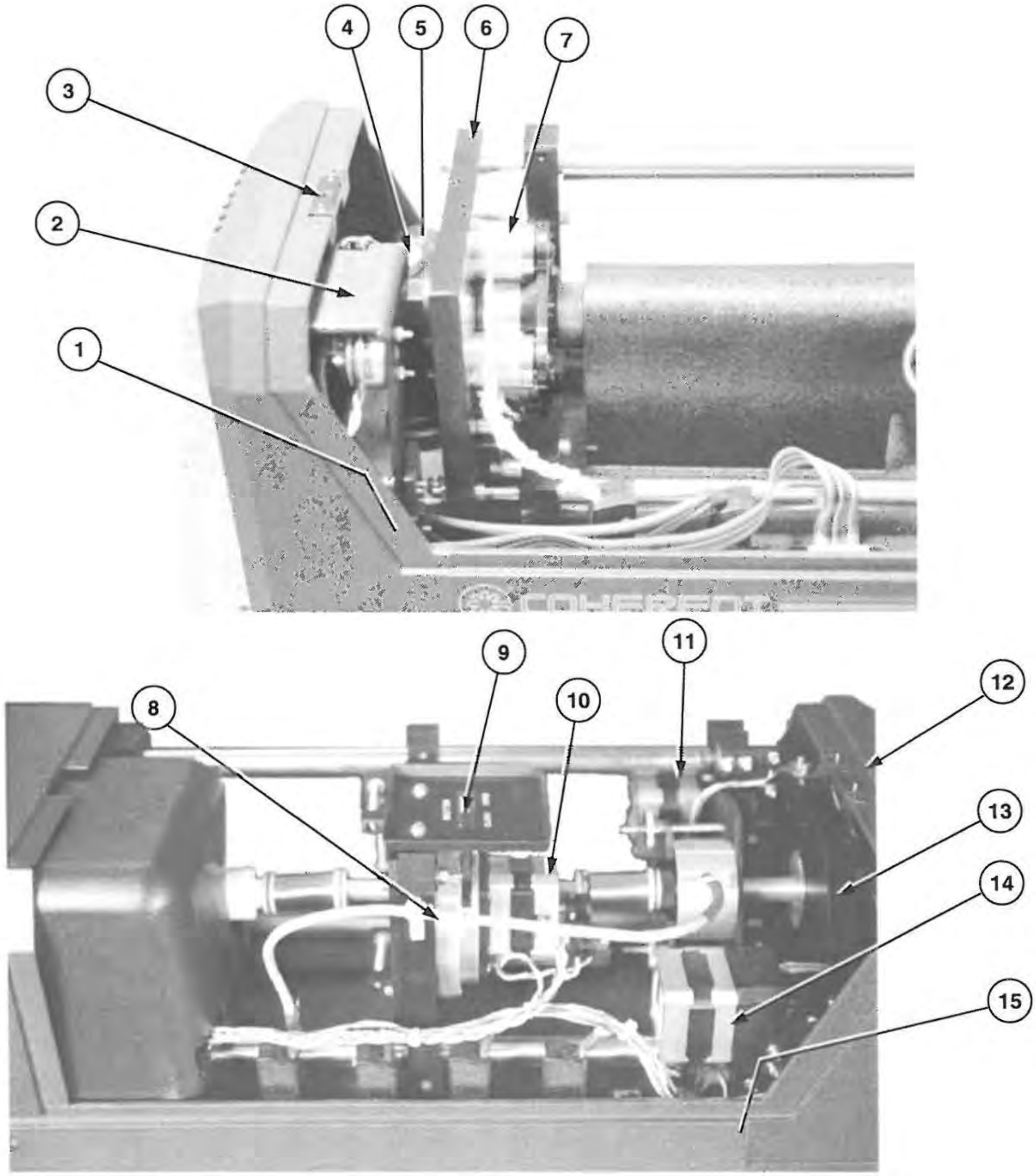
Motorized Rear Mirror Plate

Two stepper motors control the horizontal and vertical tilt of the rear mirror plate on which the high reflector is mounted (refer to Figure 5-11). Many functions are served by the automation of the rear plate which free the user of manual mechanical adjustments. If the system is operating in the single line configuration, the motorized rear plate can automatically change wavelengths. Irregardless of operation in single line or multiline configuration, if the system is not lasing, the motorized rear plate can search for the specified wavelength and optimize output power. If the system is already lasing, the motorized rear plate can adjust to maximize output power.



1. Vertical Output Coupler Mirror Plate Adjust
2. Laser Emission Indicator
3. Output Nut/Output Window (not visible)
4. Horizontal Output Coupler Mirror Plate Adjust
5. Vertical Etalon Adjust
6. Vertical High Reflector Mirror Plate Fine Adjust
7. Single Line Mirror Holder and location of Multiline Mirror Holder when installed
8. Upper Rear Bezel
9. Lower Rear Bezel
10. Feedthrough for N_2 purge
11. Feedthrough Access For Optional External Shutter Interlock Circuit
12. Horizontal High Reflector Mirror Plate Fine Adjust
13. Horizontal Etalon Adjust

Figure 5-10. Sabre Ion Laser Head, Front and Rear Views



1. TEM_{00} detector (not visible)
2. External shutter bracket
3. Front bezel interlock
4. Beamsplitter assembly
5. Photocell (not visible)
6. Output coupler mirror plate
7. PowerTrack actuators (4)
8. Automatic aperture
9. Intracavity shutter
10. Automatic aperture stepper motor
11. Vertical stepper motor
12. Rear bezel interlock
13. Motorized rear mirror plate
14. Horizontal stepper motor
15. External shutter interlock (not visible)

Figure 5-11. Sabre Laser Head – Front and Rear Interior Views

Changing Single Line Wavelengths

When the system is operating in the single line configuration, the user may change operating wavelengths within a given optic set through the remote or external computer control (Command: Wavelength = n). For example, consider a case where the standard argon visible optic set is installed, the system is lasing at 488.0 nm, and the user requires a wavelength change from 488.0 nm to 514.5 nm. To change the single line wavelength from the remote, navigate the menu tree as shown in Figure 5-12. Use the up/down arrows to select the "514.5 nm" parameter and press SELECT to initiate the procedure to change the wavelength. Upon selection, the remote will display the higher "Wavelength Menu" level.

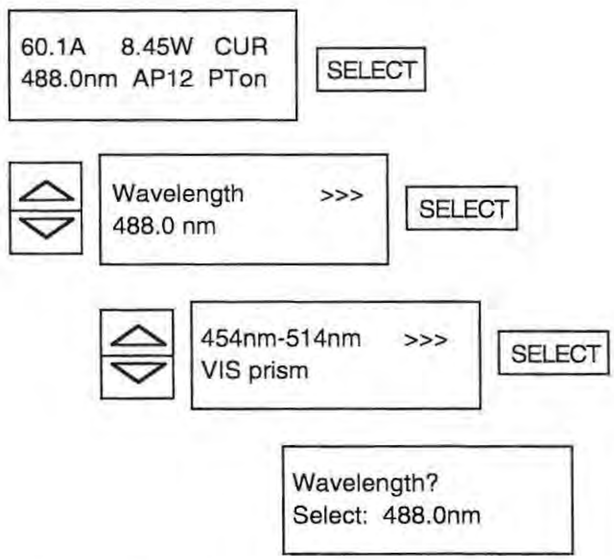


Figure 5-12. Single Line Wavelength Change Menu Path

When changing wavelengths, the system will execute the following procedures:

- The external shutter will be closed unless Auto Shutter, described in a subsequent section, is disabled.
- If PowerTrack is on, it will be temporarily turned off.
- The PowerTrack actuators will be centered.
- The aperture will be set at the OPEN position.
- The system will be set to Current Regulation Mode at maximum current.
- The motorized rear plate will be adjusted to the specified wavelength.

- The motorized rear plate will be peaked up at the specified wavelength.
- The initial aperture position, initial regulation mode, and initial specified output power or current will be restored.
- PowerTrack will be turned back on if it was on before beginning the routine.

During the procedure, the status of the motorized rear plate will be displayed in the second line of the "Wavelength Menu", refer to Figure 5-12. Additionally, the status strings, such as "Moving" will be displayed in the "Default Menu" in place of the current wavelength. The same information can be acquired through external computer control (Query: Print Motor Status). When the specified wavelength appears on the remote in the "Wavelength Menu" or in the "Default Menu", the procedure is done. Completion of the procedure can also be determined through external computer control (Query: Print Wavelength) where the response from the laser is the specified wavelength.

If any errors are encountered during the procedure, they will be displayed on the second line of the "Wavelength Menu". The same information can be acquired through external computer control (Query: Print Wavelength Errors).

To abort the procedure, navigate to the lowest menu level shown in Figure 5-12. The selection parameter displayed will be "Abort". Press SELECT to abort the procedure. Alternatively, the procedure may be aborted through external computer control (Command: Tune = 0).

If the selected single line wavelength is the same as the initial wavelength, as recognized by the system, then the system will assume that the lasing wavelength is incorrect and will proceed with the search procedure described below.

If the initial multiline wavelength is lasing and any multiline wavelength is selected, the system will be peaked for maximum power, without performing the search procedure, and the correct photocell calibration will be appropriately selected.

More information about changing optic sets or changing between the single line and multiline configurations will be given in Chapter Seven, Optics and Alignment Procedures. If the specified wavelength is not found, refer to Chapter Nine, Troubleshooting.

General Wavelength Changes

Successful operation of the motorized rear plate requires three elements: user installation of the appropriate optic set, user installation of the appropriate multiline or single line rear mirror holder, and system software recognition of the current optic set and cavity configuration. Proper execution of wavelength changes by the motorized rear plate and proper calibration of the light power photocell will then be enabled.

For the argon Sabre, four types of rear mirror holders are available for installation: multiline, visible (VIS) prism single line, ultraviolet (UV) prism single line, and deep/short ultraviolet (D/SUV) prism single line. The multiline rear mirror holder is supplied with all systems. The appropriate VIS, UV, and/or D/SUV single line holders are standard based on the system type. A distinguishing "VIS", "UV", or "D/SUV" is stamped on the intracavity face of the single line holder. More information on the multiline and single line cavity configurations is available in Chapter Ten, Theory of Operation. The multiline holder is used for general multiline operation and for the special case of 275.4 nm only. The VIS prism single line holder is used in conjunction with optic sets having bandwidths within the range of 454.5 nm to 528.7 nm. The UV prism single line holder is used in conjunction with optic sets having bandwidths within the range of 333.6 nm to 385.8 nm. The D/SUV prism single line holder is used in conjunction with optic sets having bandwidths within the range of 275.4 nm to 335.8 nm.

For the krypton Sabre, three types of rear mirror holders are available for installation: multiline, visible/infrared (VIS/IR) prism single line, and ultraviolet (UV) prism single line. The multiline rear mirror holder is supplied with all systems. The appropriate VIS/IR and/or UV single line holders are standard based on the system type. A distinguishing "VIS/IR" or "UV" is stamped on the intracavity face of the single line holder. More information on the multiline and single line cavity configurations is available in Chapter Ten, Theory of Operation. The multiline holder is used for general multiline operation. The VIS/IR prism single line holder is used in conjunction with optic sets having bandwidths within the range of 406.7 nm to 799.3 nm. The UV prism single line holder is used in conjunction with optic sets having bandwidths within the range of 337.5 nm to 356.4 nm.

The available optics sets and the part numbers of their respective high reflectors (HR) and output couplers (OC) are shown in Table 5-2 for argon and Table 5-3 for krypton. The optic set number corresponds to that accessible though

external computer control (Query: Print Optic Set). The bandwidth of each optic set corresponds to the range of available single line wavelengths and the range of lines that will lase in the multiline configuration. Refer to Appendix A for a listing of the dominant single lines. The appropriate single line holder used for each optic set is also shown in the fourth column Tables 5-2 and 5-3. The abbreviations for the multiline wavelengths displayed by the remote and used for external computer control are shown in the third column. Note that the Table 5-2 abbreviations MLDUV, MLSUV, and MLLUV correspond to multiline deep UV, short UV, and long UV respectively. Note that the Table 5-3 abbreviations MLVI, MLBG, and MLYG correspond to multiline violet, blue/green, and yellow/green respectively.

To change wavelengths in the general case, install the desired optic set into the laser head using the appropriate rear mirror holder as determined by Tables 5-2 and 5-3. Using the remote, the current optic set and cavity configuration may be made known to the system software by selection of the appropriate lower level menu in the "Wavelength Menu". Alternatively, use external computer control to specify the optic set (Command: Optic Set = n), then wavelength (Command: Wavelength = n).

Information concerning the details of the wavelength change routine and determination of the status of the motorized rear plate may be found in the preceding section titled, Laser Head and Automated Features, Motorized Rear Mirror Plate, and Changing Single Line Wavelengths. More information about changing optic sets or changing between the single line and multiline configurations is given in Chapter Seven, Optics and Alignment Procedures. If the specified wavelength is not found, refer to Chapter Nine, Troubleshooting.

Consider, as an example, an argon system that has optic sets 4 (UV) and 7 (standard VIS) available for installation. If the current operating configuration recognized by the system software is operation at 488.0 nm with the standard visible optic set and VIS prism single line holder installed, then the second line of the "Wavelength Menu" will display "488.0 nm" as shown in Figure 5-13. The lower level of the "Wavelength Menu" will display the choices shown in Figure 5-13 by pressing the up/down arrows. The first menu choice allows selection of single line wavelengths if the VIS prism single line mirror holder and standard VIS optic set (7) are installed.

Table 5-2. Argon Wavelength Selection and Optic Sets

Optic Set	Optic Set Bandwidth	Multiline Wavelength	Single Line Holder	HR	OC	Radius of OC
1	275.4 nm only [2]	275.4 nm	—	0160-493-00	0166-852-00	12 m
2	275.4 - 305.5 nm	MLDUV	D/SUV prism	0160-495-00	0166-853-00	12 m
3	300.3 - 335.8 nm	MLSUV	D/SUV prism	0161-015-00	0166-854-00	12 m
4	333.6 - 363.8 nm	MLUV	UV prism	0903-016-00	0166-855-00	12 m
5	351.1 - 385.8 nm	MLLUV	UV prism	0161-255-00	0166-856-00	12 m
6	454.5 nm only [3]	—	VIS prism	0903-004-00	0166-859-00	15 m
7	454.5 - 514.5 nm	MLVIS	VIS prism	0903-004-00	0166-858-00 or 0166-857-00 [4]	15 m
8	528.7 nm only [3]	—	VIS prism	0903-004-00	0166-860-00	10 m

[1] Single line selection is standard or available as an option dependent on optic set and system type.

[2] Requires Multiline Holder.

[3] Requires VIS Single Line Holder.

[4] Install 0166-857-00 to attain specified single line output powers of the 457.9 nm and/or Blue/Green options. Install 0166-858-00 for multiline configuration.

Table 5-3. Krypton Wavelength Selection and Optic Sets

Optic Set	Optic Set Bandwidth	Multiline Wavelength	Single Line Holder	HR	OC	Radius of OC
1	337.5 - 356.4 nm [2]	MLUV	UV prism	0903-016-00	0903-061-00	15 m
2	406.7 - 415.4 nm [2]	MLVI	VIS/IR prism	0903-062-00	0160-013-00	10 m
3	468.0 - 530.9 nm [2]	MLBG	VIS/IR prism	0903-004-00	0155-264-00 or 0161-441-00 [3]	15 m
4	520.8 - 568.2 nm	MLYG	VIS/IR prism	0903-066-00 [4]	0903-067-00 [4]	15 m
5	647.1 - 676.4 nm	MLRED	VIS/IR prism	0903-068-00	0903-070-00	10 m
6	752.5 - 799.3 nm	MLIR	VIS/IR prism	0903-064-00	0903-065-00	10 m[5]

[1] Single line selection is standard or available as an option dependent on optic set and system type.

[2] Wavelengths ≤ 468.0 nm require magnet to be set to high field.

[3] Install 0161-441-00 to attain specified single line output powers of the 468.0, 476.2, and/or 482.5 nm options. Install 0155-264-00 for multiline configuration.

[4] Install Optic Set 4 to attain specified single line output powers of the 520.8, 530.9, and/or 568.2 nm options.

[5] Radius of HR also is 10 m.

The second menu choice allows selection of single line wavelengths if the UV prism single line mirror holder and UV optic set (4) are installed. The third menu choice allows selection of multiline visible (MLVIS) or multiline ultraviolet (MLUV) operation if the multiline mirror holder with the respective standard VIS optic set (7) or UV optic set (4) is installed.

The selections available in the "Wavelength Menu" based on the different optic sets may be customized by the user through external computer control (Command: Installed Optics = n).

Wavelength Search

If the system is not lasing, the motorized rear plate can initiate a search procedure in two ways: request for a specified wavelength or request for the TUNE procedure. The routines that the system will follow in either case are nearly identical with the exception of the final wavelength attained. Request for a specified wavelength will result in a search for that wavelength. Request of the TUNE procedure will search for the current wavelength. (The TUNE procedure will be described in the next section.) In either case, ensure that the intracavity shutter, shown in Figure 5-11, is in the OPEN position.

To initiate a search for a specified wavelength, navigate the menu tree as shown in Figure 5-12. Use the up/down arrows to select the desired wavelength parameter and press SELECT to initiate the procedure to search for that wavelength. Alternatively, use external computer control (Command: Wavelength = n).

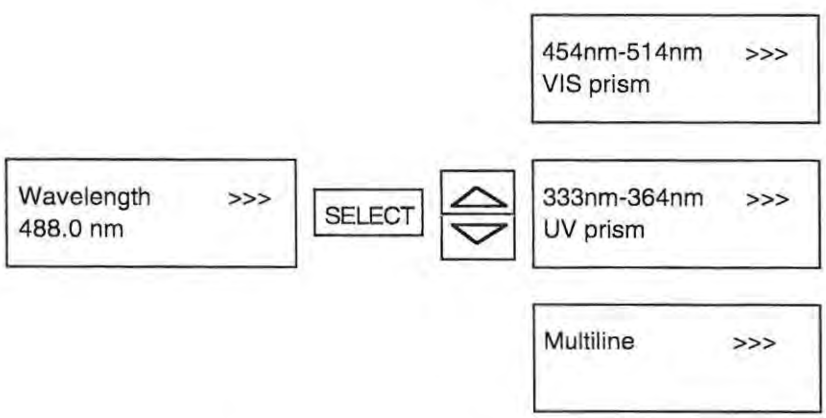


Figure 5-13. General Wavelength Change Example

The system will execute the following search procedures in response to a request for a specified wavelength when the system is not lasing or when the requested wavelength is the same as the initial wavelength:

- The external shutter will be closed unless Auto Shutter, described in a subsequent section, is disabled.
- If PowerTrack is on, it will be temporarily turned off.
- The PowerTrack actuators will be centered.
- The aperture will be set at the OPEN position.
- The system will be set to Current Regulation Mode at maximum current. If the system is not lasing, the aperture will initiate a search for the OPEN position. If the system is found to be lasing and the specified wavelength is not the same as the initial wavelength, the next step will be skipped.
- The motorized rear plate will go to its home position. It will then be adjusted to the crossover or a reference wavelength and be peaked.
- The motorized rear plate will be adjusted to the specified wavelength.
- The motorized rear plate will be peaked up at the specified wavelength.
- The initial aperture position, initial regulation mode, and initial specified output power or current will be restored.
- PowerTrack will be turned back on if it was on before beginning the routine.

The preceding section describes similarly how to determine the status and encountered errors of the motorized rear plate and how to abort the procedure. If the specified wavelength is not found, refer to Chapter Nine, Troubleshooting. If the wavelength search procedure is unsuccessful in establishing lasing, the rear mirror plate will be oriented to the position that should have lased at the specified wavelength.

TUNE Procedure

The TUNE procedure can be used in two ways: to peak up an already lasing system or to search for the current wavelength if it is not lasing. Upon successful completion of the TUNE procedure, the front and rear mirrors will be adjusted to nominal positions which maximize cavity alignment

resulting in maximum output power for current regulation or minimum tube current for light regulation. An additional result is the provision for restoration of full range for the PowerTrack alignment servo.

To access the TUNE procedure from the remote, the "Default Menu" must be displayed. Press the TUNE button on the remote to initiate the procedure. The second line of the remote will display a bar graph that represents the relative output power. The second line of the display will be restored upon completion of the procedure. To abort the TUNE procedure, press the EXIT button on the remote. A slight delay may be experienced when the procedure is interrupted to allow for completion of the current move.

The system will execute the following in response to a request for the TUNE procedure:

- The external shutter will be closed unless Auto Shutter, described in a subsequent section, is disabled.
- If PowerTrack is on, it will be temporarily turned off.
- The PowerTrack actuators will be centered.
- If the system is found to be lasing, the system will go to current regulation and the next four steps will be skipped.
- The aperture will be set at the OPEN position.
- The system will be set to Current Regulation Mode at maximum current. If the system is not lasing, the aperture will initiate a search for the OPEN position. If the system is found to be lasing, the next two steps will be skipped.
- The motorized rear plate will go to its home position. It will then be adjusted to the crossover or a reference wavelength and be peaked.
- The motorized rear plate will be adjusted to the initial wavelength.
- The motorized rear plate will be peaked up at the initial wavelength.
- The initial aperture position, initial regulation mode, and initial specified output power or current will be restored.
- PowerTrack will be turned back on if it was on before beginning the routine.

The TUNE procedure may also be accessed through external computer control (Command: Tune = 1). Display of the "Default Menu" on the remote is not required in this mode of operation. The status of the procedure may be acquired (Query: Print Tune) and the procedure may be aborted (Command: Tune = 0) through external computer control.

If any errors are encountered during the TUNE procedure, they will be displayed on the second line of the "Wavelength" menu (refer to Figure 5-12). The same information can be acquired through external computer control (Query: Print Wavelength Errors). If the TUNE procedure is unsuccessful in establishing lasing, the rear mirror plate will be oriented to the position that should have lased at the current wavelength.

Automatic Aperture and TEM_{00} Detector

The automatic aperture is used to control the transverse mode of the laser, forcing the laser to run in a single transverse mode for a given longitudinal mode. (Refer to Chapter Ten, Theory of Operation, for a further discussion of these modes.) The aperture is comprised of a rotatable wheel with a set of holes of different diameters which can be oriented to intersect the intracavity beam path. The wheel is automatically rotated to set positions by a stepper motor (refer to Figure 5-11).

The automatic aperture wheel has 20 positions: 1 through 18, OPEN (19), and CLOSED (0). Aperture positions with higher numbers correspond to larger diameter holes in the aperture wheel. Refer to Appendix B for aperture sizes. The OPEN position has a large diameter hole which will not occlude the intracavity beam in any way under normal operating conditions. The CLOSED aperture position has no hole. This position can function as a remotely operable intracavity shutter to inhibit lasing.

Any aperture position can be specified through the remote or through external computer control (Command: Aperture = n). To change the automatic aperture position from the remote, navigate the menu tree as shown in Figure 5-14. Use the up/down arrows to select the desired aperture position and press SELECT to initiate the change.

During an aperture position change, the status of the automatic aperture will be displayed in the second line of the "Aperture Menu", refer to Figure 5-14. Additionally, the status strings such as "Moving" will be displayed in the "Default Menu" in place of the current aperture. The same information can be acquired through external computer control (Query: Print Aperture Status). When the specified aperture position or TEM_{00} appears on the remote in the

"Aperture Menu" or in the "Default Menu", the procedure will be done. Completion of the procedure can also be determined through external computer control (Query: Print Aperture) where the response from the laser is the specified aperture position.

If any errors are encountered during the aperture position change, they will be displayed on the second line of the "Aperture Menu". The same information can be acquired through external computer control (Query: Print Aperture Errors).

If the user selects a specified aperture position that is the same as the current aperture position, then the aperture will search for its home position and return to the specified aperture position. The aperture error "Position reset" will be active for a short time and then be cleared.

TEM_{00} Detector

The TEM_{00} detector, shown in Figures 5-11 and 7-8, samples a portion of the output beam and measures mode beat noise to determine whether or not the system is oscillating in a single transverse mode. For special considerations concerning 488.0 nm operation, refer to Chapter Ten, Theory of Operation. The determination of operation with single transverse mode oscillation can made be through the remote or through external computer control (Query: Print TEMoo). If single transverse mode operation is detected, the current aperture position displayed in the "Default Menu" will be replaced by the string "TEMoo". Additionally, the second line of the "Aperture Menu", shown in Figure 5-14, will display the string "TEMoo" and the current aperture position. If single transverse mode operation is not detected, the current aperture position will be displayed in the "Default Menu" and the second line of the "Aperture Menu" will display the string "Manual" with the current aperture position.

The automatic aperture can also work in conjunction with the TEM_{00} detector to systematically search for and find the aperture position that results in single transverse mode oscillation or TEM_{00} oscillation. To initiate the search from the remote, navigate the menu tree as shown in Figure 5-14. Use the up/down arrows to select the "TEMoo" parameter and press SELECT to initiate the routine. Alternatively, use external computer control (Command: Aperture = 20).

The aperture size required for TEM_{00} operation is dependent on both the oscillating frequency and the laser gain at that frequency. For highest Gaussian power output, use the largest aperture setting that still maintains TEM_{00}. If mode

quality is unimportant and maximum power is desired, use the OPEN aperture position. Aperture and TEM_{00} detector alignment procedures and the measurements of the spatial profile of the output beam are discussed in Chapter 7, Optics and Alignment Procedures.

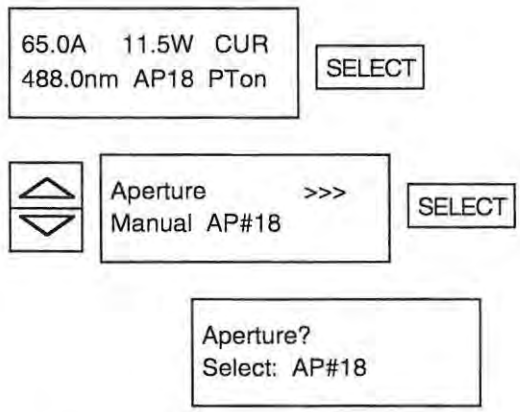


Figure 5-14. Automatic Aperture Position Change Menu Path

External Shutter

The external shutter is an extracavity water-cooled beam dump located at the front of the Sabre laser head (refer to Figure 5-11). It is provided to prohibit the lasing output beam from exiting the laser head. The external shutter may be operated manually, automatically, or in response to an external shutter interlock circuit.

Contrary to the intracavity shutter, located on the automatic aperture assembly, the external shutter does not inhibit lasing. The external shutter is best utilized in situations where it is desirable to interrupt the output beam without disturbing the lasing system. Examples of these situations include operation of a thermally stabilized system in Light Regulation Mode or operation in the single-frequency configuration.

Manual Operation

To request the system to open or close the external shutter manually from the remote, press the SHUTTER button (refer to Figure 5-1).The SHUTTER button is functional regardless of the menu displayed on the remote. Alternatively, use external computer control for external shutter manual operation (Command: Shutter = n).

The status of the external shutter hardware and its requested state are indicated by the LED above the SHUTTER button. The LED above the SHUTTER button will be on if the shutter

was requested to be open or if the hardware had sensed it to be open. The LED will be off only when the requested state was closed and the hardware had sensed it to be closed. Alternatively, use external computer control for acquisition of external shutter status (Query: Print Shutter).

When the system is in start delay, pressing the SHUTTER button will toggle the requested state between open and closed. The shutter hardware will be kept closed during the start delay sequence regardless of the requested state. If open is the requested state, then the shutter will open upon completion of the start delay sequence.

Auto Shutter

The external shutter can be set to automatically close when certain events occur. The Auto Shutter feature provides protection for optical elements in the external path from sudden changes in output power. The events which utilize the Auto Shutter include initiation of the start delay sequence to ionize the plasma tube, initiation of the TUNE procedure, and requests for wavelength or aperture position changes. The external shutter will be closed at the instigation of each event and will remain closed indefinitely. Manual operation of the external shutter is available immediately after an automatic close.

To enable or disable the Auto Shutter feature or check its status from the remote module requires the extended menus to be displayed on the remote (Sabre Power Supply DIP switch 8 on MY TALK ADDRESS = ON). Navigate the menu tree as shown in Figure 5-15. Use the up/down arrows to select the desired "Yes" or "No" parameter and press SELECT.

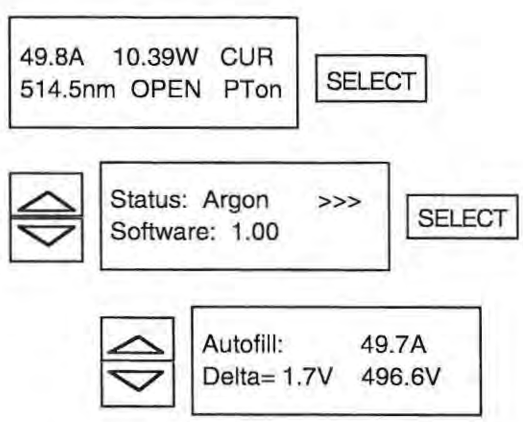


Figure 5-15. Auto Shutter Menu Path

The Auto Shutter feature may also be enabled or disabled (Command: Auto Shutter = n) and its status may be acquired (Query: Print Auto Shutter) through external computer control.

Auto Exposure

A built–in timer is provided to work in conjunction with the external shutter. If the external shutter is initially closed, the Auto Exposure feature will open the external shutter for a user specified length of time and then close. If the external shutter is initially open, the Auto Exposure will close the external shutter after the specified length of time.

To enable the Auto Exposure feature from the remote module requires the extended menus to be displayed on the remote (Sabre Power Supply DIP switch 8 on MY TALK ADDRESS = ON). Navigate the menu tree as shown in Figure 5-16. Use the up/down arrows to select the desired exposure time and press SELECT to initiate. The exposure time may be in the range of 0.1 to 3250.0 seconds.

An Auto Exposure in process may be canceled from the remote in two ways: navigate the menu tree as shown in Figure 5-16 and select an exposure time of 0.0 seconds or use the SHUTTER button on the remote. The Auto Exposure feature will be canceled by initiation of or operation during the start delay sequence.

The Auto Exposure feature may also be enabled (Command: Exposure = n.n) and canceled (Command: Exposure = 0.0 or Command: Shutter = 0 or 1) through external computer control.

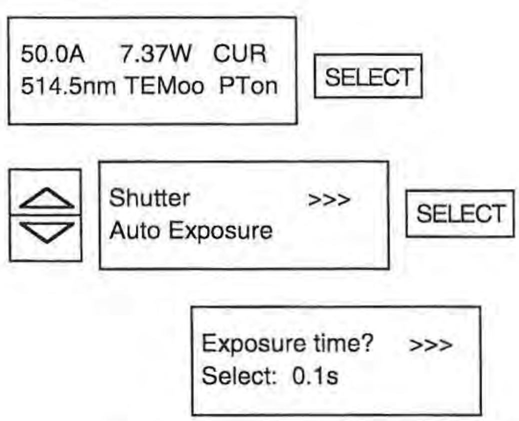


Figure 5-16. Auto Exposure Menu Path

External Shutter Interlock

An External Shutter Interlock circuit may be wired to a door switch to close the external shutter when a person enters a designated restricted area. The external shutter interlock is located in the rear of the Sabre laser head, as shown on Figure 5-11. The two terminals of terminal block must be connected for the external shutter to operate. The factory installed jumper may be replaced with an external shutter interlock circuit.

The external shutter interlock has an open circuit voltage of 22 to 26 VDC and a short circuit current of ≤ 750 mA. Under no circumstances should an external voltage or current source be connected to this circuit. If the external resistance connected between the terminals is less than 0.1 Ω, the external shutter is functional and will operate from the remote or external computer control. If the resistance is greater than 100,000 Ω, the external shutter is disabled and closed and will not operate. To assure proper functioning of your external shutter, design your external shutter interlock circuit to have a resistance less than 0.1 Ω when closed and a resistance greater than 100,000 Ω when open. External shutter interlock circuitry should be isolated from all other electrical circuits or grounds.

PowerTrack

PowerTrack is an active stabilization loop that automatically maintains optimum cavity alignment by servo control of the output coupler tilt angle. (For a detailed description, refer to Chapter Ten, Theory of Operation). In normal operating conditions, it is recommended to have PowerTrack On at all times.

Modes of PowerTrack Operation

The user can typically encounter one of four modes of the status of PowerTrack operation: On and operating, parked, out of range, or Off completely.

Due to the nature of the servo loop, PowerTrack is On and operational only when the system is lasing above a certain threshold level. This mode of operation is the one most commonly encountered in daily operation.

With PowerTrack is On, the system may be temporarily unable to control the output coupler tilt. In this case PowerTrack will "park". When PowerTrack is parked, it will hold and maintain the current output coupler tilt angle until conditions warrant continuation of normal operation. PowerTrack will be parked if the system is not lasing or is

lasing below a certain threshold level. Examples of these situations include a closed intracavity shutter or a grossly misaligned cavity. PowerTrack will be parked temporarily in response to transient events. Examples of these events are sudden changes in tube current or light power settings when photocell gain switching occurs. PowerTrack will also be parked indefinitely when operating in the Reduced Bandwidth Light Regulation Mode (LT–). This mode of operation will be described in a subsequent section and related sub-sections titled: LIGHT REGULATION MODE.

It is possible for PowerTrack to go out of range and park indefinitely. It will then be required of the operator to recenter PowerTrack in its range and optimize cavity alignment with the motorized rear mirror plate. To accomplish this, leave PowerTrack On and initiate the TUNE procedure, as described in a previous section, to recenter PowerTrack and peak up the system. Upon completion of the TUNE procedure, PowerTrack will be On and operational and will regain its full range for cavity alignment optimization.

Activation of PowerTrack

To turn PowerTrack On or Off from the remote, press the PWR TRK button (refer to Figure 5-1). The PWR TRK button is functional irregardless of the menu displayed on the remote. When PowerTrack is turned On, "PT On" will be displayed in the lower right corner of the "Default Menu" as shown in Figure 5-17.

When PowerTrack is turned Off, "PT Off" will be displayed in the "Default Menu". Alternatively, use external computer control to turn PowerTrack On of Off (Command: PowerTrack = 1 or 0).

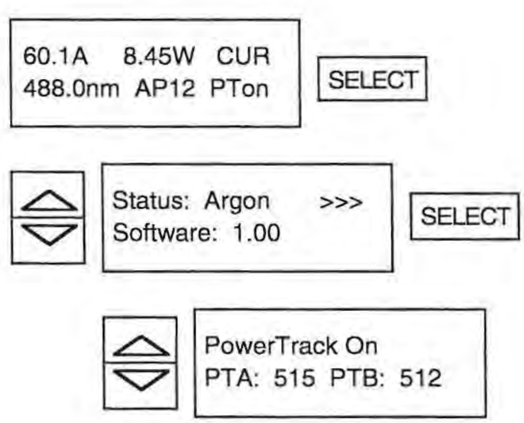


Figure 5-17. PowerTrack Status Menu Path

Acquisition of PowerTrack Status

The status of PowerTrack operation is indicated by the lower right corner of the "Default Menu" in conjunction with the LED above the PWR TRK button (refer to Figure 5-1). Alternatively, use external computer control for acquisition of PowerTrack status (Query: Print PowerTrack). The status of PowerTrack may also be acquired by navigating the menu tree as shown in Figure 5-17 and observing the top line of the "PowerTrack Status Menu".

The second line of the "PowerTrack Status Menu", shown in Figure 5-17, contains information of the measured analog to digital conversion (ADC) readings of the PowerTrack DACs for A (vertical) and B (horizontal). The readings represent the relative tilt angles of the output coupler about the vertical and horizontal axes. The DAC values can be in the range of 0 to 1023. PowerTrack will go out of range if either of these values is less than 25 or greater than 999. When operating in the single-frequency cavity configuration, PowerTrack will go out of range at values dependent on the current ZDAC value. For a complete discussion, see Chapter Eight, Single-Frequency Operation. The read DAC values may also be acquired through external computer control (Queries: Print PTDACA and Print PTDACB).

Table 5-4 illustrates the indications by the "Default Menu", the LED above the PWR TRK button, and the top line of the "PowerTrack Status Menu" in response to the four basic modes encountered in typical PowerTrack operation.

If PowerTrack is On, "PT On" will be displayed in the "Default Menu". When PowerTrack is operating normally, the LED above the PWR TRK button will be continuously illuminated. The top line of the "PowerTrack Status Menu" will read "PowerTrack On".

Table 5-4. PowerTrack Status Indications

PowerTrack Status	Display on Default Menu	PWR TRK LED	Top Line of PT Status Menu
PT On and Operational	PT On	On	PowerTrack On
PT On and Parked	PT On	Off	PowerTrack Parked
PT Out of Range and Parked	PT On	Flashing	PwrTrk Out of range
PT Off	PT Off	Off	PowerTrack Off

When PowerTrack is parked, the LED will be off and the status entry will be "PowerTrack Parked". When PowerTrack is out of range and parked, the LED will be flashing and the status entry will be "PwrTrk Out of range".

If PowerTrack is turned Off, "PT Off" will be displayed and the LED above the button will be off. The top line of the "PowerTrack Status Menu" will read "PowerTrack Off".

PowerTrack Calibration

For optimum performance for a particular wavelength or power level, the gain of the PowerTrack control loop can be calibrated. This procedure is typically performed infrequently and is at the discretion of the user. For single-frequency operation, calibrate PowerTrack in single line operation before installing the etalon. Do not initiate a calibration routine when the system is lasing in single-frequency. Refer to Chapter Eight, Single-Frequency Operation for more information on this cavity configuration.

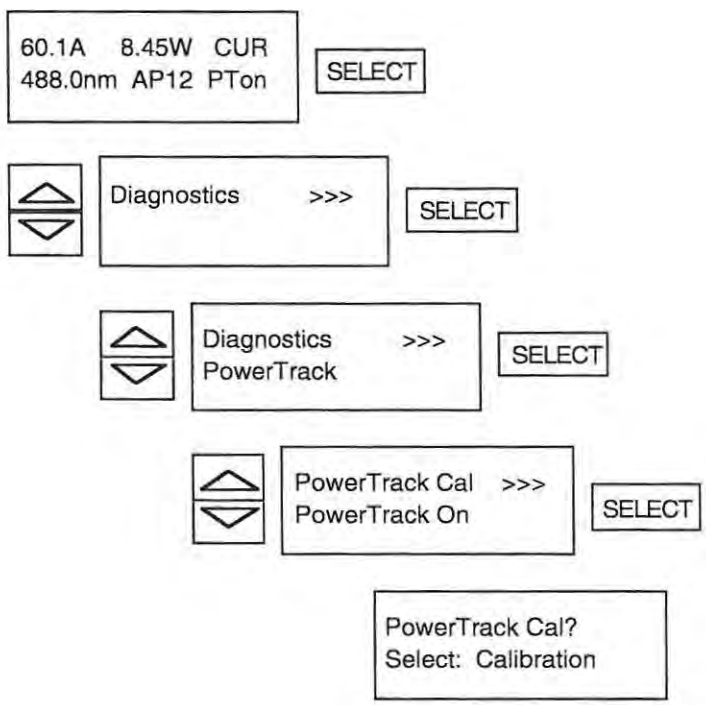


Figure 5-18. PowerTrack Calibration Menu Path

Before initiating the calibration routine, ensure that the system is lasing in Current Regulation Mode with PowerTrack On. To access the PowerTrack calibration procedure from the remote module requires the extended menus to be displayed on the remote (Sabre Power Supply DIP switch 8 on MY TALK ADDRESS = ON). Navigate the menu tree as shown in Figure 5-18. Press SELECT to initiate the calibration procedure. Alternatively, use external computer control (Command: PowerTrack = 2).

During PowerTrack calibration, the output power will fluctuate rapidly. The second line of the "PowerTrack Cal Menu" will display the string "PwrTrk Calibrating". This procedure will take approximately 15 seconds and then PowerTrack will resume. The calibration loop gain will be stored in memory.

Purged Systems

Argon Sabre systems equipped with the deep or short UV options include purge kits. The purge kit consists of a variable flowmeter, necessary connectors and hoses, and special intracavity parts: vented bellows for the Brewster windows, a vented rear mirror transition tube, and a unique output coupler mirror holder. A positive pressure of nitrogen in the intracavity space helps inhibit ozone build-up which can degrade performance especially in the deep UV lines.

A user-supplied source of dry nitrogen is required on purged systems. The recommended grade of bottled nitrogen has a minimum purity of 99.999% and is sometimes known as scientific grade. A high purity "boil-off" nitrogen source may be used as an alternative. Dry air may not be used as it contains oxygen which can be converted to ozone by the deep UV produced by the plasma discharge.

The variable flowmeter should be installed, in accordance with the manufacturer's instructions, between the nitrogen source and the laser head . The recommended flow rate, as indicated by the flowmeter, is 1.0 ± 0.5 SCFH (cubic feet per hour at standard flow temperature and pressure). The purge line attaches to the rear of the laser head at the location shown in Figure 5-10. The flow of nitrogen should be established well in advance of system ionization, or maintained continuously, to remove any atmospheric oxygen and/or water vapor from the intracavity space.

The nitrogen flows into the laser head and is split into two paths to the front and rear intracavity spaces. The bellows at the Brewster windows have small venting holes drilled into the last "fold" of the bellows. Ensure that the ends of the

bellows with the venting holes are oriented to seal around the Brewster window stems. The connection where purge line mates with the front bayonet mount may be detached when necessary by pulling the purge line off of the plastic nipple on the bayonet mount. Try to avoid possible contamination of the free end of the purge line and/or the nipple fitting while they are detached.

Remote Control Module

The remote control module features ten pushbutton controls, a Liquid Crystal Display (LCD), a LASER EMISSION indicator, and four LEDs, as shown in Figure 5-19. Virtually all system functional controls are accessible through the remote control module providing for "hands off" operation of the Sabre ion laser. The remote also displays system status, operating parameters, and fault messages. A general overview of operation of the remote and its menu tree has been described at the beginning of this chapter in the section titled, REMOTE BASICS. Some of the functions accessible through the remote pertaining to the Sabre heat exchanger and the automated features of the laser head have also been described in previous sections in this chapter. The following sections describe in detail the remaining controls and menus available for display from the remote control module.

The remote control module is connected to the Sabre power supply by a 4.9 m (16 ft.) telephone cable. The system may be operated through external computer control with or without the remote control module connected to the power supply. However if the remote is disconnected for more than 10 seconds while the system keyswitch is ON, a "Remote Interlock" fault will occur and the system will prohibit ionization. (More information on this and other faults will be discussed in Chapter Nine, Troubleshooting.)

On the rear of the remote control module is a small access hole labeled "VIEW ANGLE". A small insulated straight blade screwdriver, such as a pot tweaker, may be inserted and the small white screw potentiometer inside may be rotated approximately one full turn. This allows for adjustment of the LCD display view angle for best visibility as room lighting conditions dictate.

The remote is capable of displaying a standard set and an extended set of menus. To enable access to the extended menus, set switch 8 on the MY TALK ADDRESS DIP switch on the rear panel of the Sabre power supply to the up (ON) position.

Faults

The microprocessor in the Sabre power supply constantly monitors operating parameters for faults whenever the keyswitch is ON. If a fault is detected, the system will de-ionize and a fault message will appear on the remote control module on the top line of the "Default Menu".

Alternatively, use external computer control for acquisition of current faults (Query: Print Faults). For more information about system recognized fault messages, refer to Chapter Nine, Troubleshooting.

The system can not be ionized until the fault is corrected. When the fault is corrected, the fault message may be cleared from the "Default Menu" by pressing the ON button to initiate the start delay sequence or by cycling the keyswitch OFF then ON.

Figure 5-19. Sabre Remote Control Module

Laser Emission Indicator

When the ON/OFF button is pressed to initiate the start delay sequence to ionize the plasma tube, the LASER EMISSION indicator on the remote control module will illuminate to warn that the laser will soon ionize. This indicator will remain illuminated until the laser is de-ionized.

Default Menu

The "Default Menu" that appears on the LCD display when the keyswitch is first turned ON is a member of the highest menu level. It can be accessed from any lower menu level by repeatedly pressing the EXIT button until it is displayed. The

MEMORY and TUNE buttons are only functional when the "Default Menu" is displayed. The "Default Menu" can assume one of three forms determined by the system status as shown in Figure 5-20.

The form that the "Default Menu" assumes when the keyswitch is first turned ON, as shown in Figure 5-20 (a), is the same as is displayed after de-ionization or when a fault is detected. The first line will normally display the string "Laser Off". If a fault is detected, a fault message will appear on the top line of the display (refer to Chapter Nine, Troubleshooting). While in this display, the user may select Current or Light Regulation Mode by pressing the LIGHT button. The second line will indicate the current or light power at which the laser will start up. Use the up/down arrows to specify the desired current or light power. Alternatively, use external computer control (Commands: Current = nn.nn or Light = nn.nnnn).

The form of the "Default Menu", shown in Figure 5-20 (b), is displayed when the ON button is pressed on the remote to initiate the start delay sequence for ionization or when a request to turn the system on is issued through external computer control (Command: Laser = 1). The number on the first line indicates the time in seconds remaining in the 75 second sequence and will count to zero before the plasma tube ionizes.

(a)
```
Laser Off
Turn On:  50.1 A
```

(b)
```
Start Delay:  25
Turn On:  50.1 A
```

(c)
```
50.1A    7.45W   CUR
514.5nm TEMoo  PTon
```

a) Initial keyswitch ON
b) During start delay sequence
c) System ionized

Figure 5-20. Three Forms of the Default Menu

The main contactor engages in the power supply and may be audible when the time remaining reaches approximately 50 seconds. The time remaining in the start delay sequence may also be acquired through external computer control (Query: Print Start). The Current or Light Regulation Mode and setting may be changed, as previously described, when this form of the "Default Menu" is displayed.

When the system is ionized, the "Default Menu" will assume the form shown in Figure 5-20 (c). The two lines of the display are each divided into three fields that indicate current system operating parameters.

The first line of the display is divided into three fields: current, power, and regulation mode. The third field in the first line indicates the regulation mode that the laser is operating in. The regulation mode may be acquired through external computer control (Query: Print Mode). The regulation mode determines what is displayed in the first two fields. In Current Regulation Mode, the third field displays "CUR" and the first field indicates the user specified tube current while the second field indicates the measured light power. The third field displays "LT" in standard Light Regulation Mode or "LT–" in Reduced Bandwidth Light Regulation Mode and the first field indicates the measured tube current while the second field indicates the user specified light power. The up/down arrows on the remote control module are used to select the user specified values in either regulation mode. (The special case of Light Regulation out of range and a detailed description of the different regulation modes will be described in the subsequent section and related sub-sections: CURRENT REGULATION MODE and LIGHT REGULATION MODE.)

The example shown in Figure 5-20 (c) displays the string "CUR" in the third field of the top line and indicates that the system is operating in the Current Regulation Mode. The first field in the top line shown in Figure 5-20 (c), displays "50.1 A" and indicates the user specified current. The second field in the top line shown in Figure 5-20 (c), displays "7.45 W" and indicates that as the measured light power.

Using external computer control, Current Regulation Mode may be set and the tube current may be specified to the nearest 0.01 A (Command: Current = nn.nn). The specified tube current may be acquired (Query: Print Set Current). The measured light power may be acquired (Query: Print Light).

Using external computer control, Light Regulation Mode may be set and the light power may be specified to the nearest

0.0001 W (Command: Light = nn.nnnn). The specified light power may be acquired (Query: Print Set Light). The measured tube current may be acquired (Query: Print Current).

The second line of the "Default Menu" shown in Figure 5-20 (c) is divided into three fields: wavelength, aperture or TEM_{00} indication, and PowerTrack mode. The first field in the second line shown in Figure 5-20 (c) displays "514.5nm" as the current wavelength setting. When the wavelength setting is changed, the first field will display status strings such as "Moving" until the wavelength change procedure is completed. The information displayed in this field may be set (Command: Wavelength = n) or acquired (Queries: Print Wavelength or Print Motor Status) using external computer control.

The second field in the second line shown in Figure 5-20 (c) displays "TEM_{00}" and indicates that the system is operating with single transverse mode oscillation. For the special case of 488.0 nm operation, refer to Chapter Ten, Theory of Operation. If the system were not oscillating with a TEM_{00} mode, then this field would display the current aperture position. For example, "AP#18" would be displayed if 18 was the current aperture position and multiple transverse modes were detected. When the aperture setting is changed, the second field will display "Moving" until the aperture change procedure is completed. The information displayed in this field may be set (Command: Aperture = n) or acquired (Queries: Print Aperture or Print Aperture Status or Print TEMoo) using external computer control.

The third field in the second line shown in Figure 5-20 (c) displays "PT on" and indicates that PowerTrack is requested to be On. If PowerTrack were turned Off, the field would indicate "PT off". The information displayed in this field may be set (Command: PowerTrack = n) or acquired (Query: Print PowerTrack) using external computer control.

Special cases affecting the "Default Menu" shown in Figure 5-20 (c) include execution of the TUNE procedure which replaces the second line of the display with a bar graph indicating relative output power. Also, if the Automatic Aperture or PowerTrack are not installed in the system, then the second and third fields of the second line, respectively, will be blank.

Pushbutton Controls - Menu Navigation and Selection

There are ten pushbuttons on the remote control module to allow the operator to control and monitor the Sabre ion laser. Brief descriptions of these buttons have been previously described in the section titled, REMOTE BASICS, at the beginning of this chapter. The EXIT and SELECT buttons are used for menu tree navigation and parameter selection. The up/down arrows operate independently and in conjunction with other buttons.

Information displayed on the remote control module is organized in a menu tree. The menu tree consists of several menu levels that branch out from high to low. There may be one or more members within each menu level. The "Default Menu" that appears when the keyswitch is first turned ON is a member of the highest menu level. Subsequent menu levels display >>> in the upper right corner if a lower menu level exists.

EXIT and SELECT

The EXIT and SELECT buttons serve complimentary functions in menu tree navigation and parameter selection. The SELECT button can be used to enter the next lowest menu level is one exists. The EXIT button can be used to move up to a higher menu level. From any menu level, repeated pressing of the EXIT button will eventually navigate to the highest menu level, the "Default Menu".

Within lower menu levels, a particular menu may allow the user to change an operating parameter. Any parameter after the word "Select:" is variable. The up/down arrows may be used to scroll through the available options. To initiate the change to the user specified parameter, press the SELECT button. To cancel selection of the variable parameter within that menu level, press the EXIT button to cancel the change, retain the current operating parameters, and move up one menu level.

Up/Down Arrows

Located at the right of the ten pushbuttons on the remote are two buttons marked with up and down arrows. These are referred to as the up/down arrows or the scroll buttons. When the "Default Menu" is displayed the remote, the up/down arrows are used to adjust the current setting (in Current Regulation Mode) or the power output setting (in Light Regulation Mode). In the memory mode of operation, the scroll buttons are used to select between two memory settings. In lower menu tree levels, the up/down arrows are used in menu tree navigation to scroll through the members of a given menu level. When selecting an operating

parameter in a lower menu level, the up/down arrows are used to scroll through the parameters available for selection.

Pushbutton Controls - Dedicated Buttons

Six buttons on the remote control module are dedicated to specific functions: ON/OFF, MEMORY, TUNE, PWR TRK, SHUTTER, and LIGHT. Brief descriptions of these buttons have been previously described in the section titled, REMOTE BASICS, at the beginning of this chapter.

ON/OFF

The ON/OFF button is used to ionize and de-ionize the laser plasma tube. The ON/OFF button will operate at all times irregardless of the display on the remote module. When pressed ON, the start delay sequence is initiated with a 75 second countdown. The Sabre heat exchanger will turn on and circulate cooling water by application of power to its pump. The external shutter will close. Power will be applied to the cathode circuitry. With 50 seconds remaining in the countdown, the power supply main contactor will engage providing tube voltage and magnet current. At zero seconds, the starter will fire resulting in ionization of the plasma tube.

When pressed OFF, the main contactor will open resulting in de-ionization of the plasma tube. Power to the magnet and cathode will be turned off. The heat exchanger will execute its 5 minute cool down period with continuation of cooling water circulation through the system. The power to the heat exchanger pump will be removed upon completion of the cool down period.

MEMORY

To activate the memory mode of operation, press the MEMORY button while the "Default Menu" is displayed. When the system is in the memory mode of operation, the LED above the MEMORY button will be illuminated. The up/down arrows can then be used to select memory level 1 or 2 if the "Default Menu" is displayed. The system operating parameters that are stored in the memory levels include: regulation mode, specified current or light setting dependent on the regulation mode, wavelength setting, PowerTrack On or Off, and aperture setting. To de-activate the memory mode of operation, press the MEMORY button while the "Default Menu" is displayed. The LED above the MEMORY button will be off.

MEMORY LEVELS AND EXTERNAL COMPUTER CONTROL

Memory levels 1 and 2 can be stored or recalled from the remote. These memory levels are the same as those that are available through external computer control (Commands: Store Memory n or Recall Memory n). External computer control provides memory levels 0 through 9. It is possible to acquire system operating parameters stored in each memory level through external computer control (Queries: Print Memory n Mode, Print Memory n Setpoint, Print Memory n Wavelength, Print Memory n PowerTrack, and Print Memory n Aperture). Note that recall of memory level 1 or 2 from external computer control will not illuminate the LED above the MEMORY button and put the system in the memory mode of operation. This mode of operation is unique to the remote control module. Additionally, external computer control cannot be used to de-activate the memory mode of operation. De-activation of the memory mode of operation may only be executed through the remote.

STORING MEMORY LEVELS

To store the current system operating parameters in memory level 1 or 2 from the remote module, navigate the menu tree as shown in Figure 5-21. The second field of the second line of the lowest menu level shown in Figure 5-21 displays "Mem1" and indicates that the current operating parameters will be stored in memory level 1. Use the up/down arrows to select either memory level 1 or 2 for parameter storage. Press SELECT to store the displayed parameters in the desired memory level.

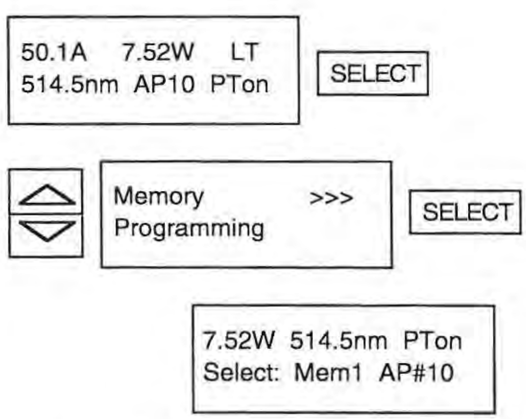


Figure 5-21. Memory Programming Menu Path

The lowest menu level shown in Figure 5-21 displays the current system operating parameters that can be stored in memory level 1 or 2. The first field of the top line displays "7.52W" and indicates that the Light Regulation Mode with an output power of 7.52 W will be stored. If Current Regulation Mode is the present operating mode, the first field of the top line will display the tube current setting. The LIGHT button may be pressed while in this menu level to toggle between Current or Light Regulation Mode, however, to change the setpoint in either regulation mode using the up/down arrows requires navigation up to the "Default Menu".

The second field of the top line of the lowest menu level shown in Figure 5-21, displays "514.5nm" and indicates the wavelength setting that will be stored. The third field of the top line displays "PTon" and indicates that PowerTrack On will be stored.

While in this menu level, the PWR TRK button may be pressed to turn PowerTrack On or Off before storing this parameter. The third field of the second line displays "AP#10" and indicates that the current aperture position of 10 will be stored. Note that the valid aperture positions that can be stored are 1 through 18, OPEN, and CLOSED. The system will not initiate a search for the aperture position giving TEM_{00} through a memory level recall.

RECALLING MEMORY LEVELS

To recall the system operating parameters stored in memory level 1 or 2 from the remote requires the "Default Menu" to be displayed. Press the MEMORY button to enable the memory mode of operation. A menu similar to that shown in Figure 5-22 will be displayed. The memory level 1 operating parameters displayed on the top line of the menu may be activated by pressing the up arrow button. The memory level 2 operating parameters displayed on the second line of the menu may be activated by pressing the down arrow button. Subsequent pressing of the up/down arrows while in the memory mode of operation with the "Default Menu" displayed will select the appropriate memory levels. Once a memory level is selected upon initiation of the memory mode of operation, the memory recall menu shown in Figure 5-22 will not be displayed again until the memory mode of operation is de-activated and re-activated.

The two lines of the memory recall menu shown in Figure 5-22 each contains four fields. The first field indicates the current or light regulation setting of the appropriate memory

level. The second field indicates the respective wavelength settings. The third field will display a "P", as shown in Figure 5-22, if PowerTrack will be On for that memory level. The third field will be blank if PowerTrack will be Off for that memory level. The fourth field indicates the aperture position for the respective memory level. In the example illustrated in Figure 5-22, memory level 1 operating parameters are 7.52 W of Light Regulation Mode at 514.5 nm with PowerTrack On and an aperture setting of 10. Memory level 2 operating parameters are 60.1 A of Current Regulation Mode at 457.9 nm with PowerTrack On and an OPEN aperture setting.

If the memory mode of operation is not desired while the "Memory Recall Menu", shown in Figure 5-22, is displayed, press the EXIT or MEMORY button to de-activate it.

```
7.52W 514.5nm  P  10
60.1A  457.9nm  P  OP
```

Figure 5-22. Memory Recall Menu

TUNE

The TUNE button is operational only from the "Default Menu". Pressing the button initiates the TUNE procedure to peak up an already lasing system or to search for the current wavelength if it is not lasing. The second line of the "Default Menu" on the remote will display a bar graph that represents the relative output power during the procedure. To abort the TUNE procedure, press the EXIT button on the remote. A detailed description of the use of the TUNE button and the procedure it initiates can be found in the previous sub-section: LASER HEAD AND AUTOMATED FEATURES: Motorized Rear Mirror Plate: TUNE Procedure.

PWR TRK

The PWR TRK button is operational from any menu level. Pressing the button turns PowerTrack On or Off. The operational status of PowerTrack may be obtained from the third field of the "Default Menu" in conjunction with the LED above the PWR TRK button or from the PowerTrack status menu shown in Figure 5-17. A detailed description of the implementation of the PWR TRK button in system control can be found in the previous section and related sub-sections: LASER HEAD AND AUTOMATED FEATURES: PowerTrack.

SHUTTER

The SHUTTER button is used to open or close the external shutter located in the Sabre laser head. An illuminated LED above the SHUTTER button indicates a requested or actually open external shutter. An extinguished LED above the SHUTTER button indicates a requested and actually closed external shutter. During the start delay sequence, the external shutter hardware is held closed. The shutter hardware will then be opened or left closed, dependent on the user-requested state, upon completion of the start delay sequence. A detailed description of the implementation of the SHUTTER button can be found in the previous section and related sub-sections: LASER HEAD AND AUTOMATED FEATURES: External Shutter.

LIGHT

The LIGHT button is used to select system operation in the Light Regulation Mode (constant output power) or Current Regulation Mode (constant tube current). Press the LIGHT button to toggle between Light and Current Regulation Modes. The up/down arrows on the remote control module are used to select the user specified values in either regulation mode when the "Default Menu" is displayed. More information about the different system regulation modes will be presented in the subsequent sections and related sub-sections: CURRENT REGULATION MODE and LIGHT REGULATION MODE

The status of the present system regulation mode may be determined from the remote through observation of the LED above the LIGHT button in conjunction with the upper right hand corner of the "Default Menu". The regulation mode may also be acquired through external computer control (Query: Print Mode). Table 5-5 illustrates the possible combinations of the status of the LED above the LIGHT button and the upper right hand corner of the "Default Menu" in response to several different scenarios of requested regulation modes and operating conditions.

The LED above the LIGHT button indicates the regulation mode that was requested by the user. If the LED is steadily illuminated or flashing, then Light Regulation Mode was requested. If the LED is off, then Current Regulation Mode was requested. The upper right hand corner of the "Default Menu" indicates the regulation mode that the system is currently operating in irregardless of the requested regulation mode.

The system regulation mode presently operating may be different than the requested regulation mode. This situation may be temporary. An example of such a situation could be a requested regulation mode of standard light. The system will

temporarily operate in Reduced Bandwidth Light Regulation Mode during re-calibration of the light regulation gain circuitry. This example is illustrated by the third entry of Table 5-5. The present regulation mode may also be sustained indefinitely, such as a situation where Light Regulation Mode was requested but the intracavity shutter was closed. The system would try to achieve the requested light setting but would go out of range by operating at maximum current. The system would then maintain Current Regulation Mode until sufficient light can once again be detected and Light Regulation Mode can be restored. This example is illustrated by the fourth and sixth entries of Table 5-5.

Table 5-5. Regulation Mode Status Indications

Regulation Mode	Display on Default Menu	LED above LIGHT Button
Current	CUR	Off
Standard light	LT	On
Standard light: while re-calibrating gain	LT–	On
Standard light: out of range	CUR	Flashing
Reduced Bandwidth light	LT–	On
Reduced Bandwidth light: out of range	CUR	Flashing

Current Regulation Mode

Selection of the Current Regulation Mode may be toggled by pressing the LIGHT button on the remote when the "Default Menu" is displayed. When Current Regulation Mode is active, the plasma tube current is kept constant. The LED above the LIGHT button will be off. The upper right hand corner of the "Default Menu" will display "CUR". The up/down arrows will change the tube current setting when the "Default Menu" is displayed. Using external computer control, Current Regulation Mode may be set and the tube current may be specified to the nearest 0.01 A (Command: Current = nn.nn). The specified tube current may be acquired (Query: Print Set Current).

In Current Regulation Mode, the tube current will not change if the intracavity optical beam path is interrupted or misaligned. It is recommended that Current Regulation Mode be used when mirror alignment or optics changes are necessary. Current Regulation Mode is also recommended for situations where the system thermal stabilization has not

yet been attained and may be required for optimum performance such as initial operation in the single-frequency cavity configuration. (Refer to Chapter Eight, Single-Frequency Operation for more information.)

The system is automatically switched to Current Regulation Mode when several procedures are initiated. The switch to Current Regulation Mode may be temporary or may be maintained indefinitely depending on the procedure executed. Any of the procedures involving movement of the motorized rear mirror plate or automatic aperture (except for a TEM_{00} search in light regulation) will temporarily engage Current Regulation Mode until successful completion of each procedure. Light Regulation Mode out of range will cause the system to operate in Current Regulation Mode until the situation is remedied. The single-frequency routines, ModeTune and ModeFineTune, put the system in Current Regulation Mode for procedure execution and maintain it upon completion. The autofill calibration procedure available through external computer control (Command: Calibrate Autofill = 1) also invokes Current Regulation Mode for the duration of the procedure and an indefinite time thereafter.

Light Regulation Mode

Selection of the Light Regulation Mode may be toggled by pressing the LIGHT button on the remote when the "Default Menu" is displayed. When Light Regulation Mode is active, the laser output power is held to a fixed level. The LED indicator above the LIGHT button will be steadily illuminated. The upper right hand corner of the "Default Menu" will display "LT" or "LT–". The up/down arrows will change the output power setting when the "Default Menu" is displayed. Using external computer control, Light Regulation Mode may be set and the light power may be specified to the nearest 0.0001 W (Command: Light = nn.nnnn). The specified light power may be acquired (Query: Print Set Light).

The Sabre ion laser should be used in Light Regulation Mode whenever precise control of the output power is required. The laser output power is measured using a temperature stabilized photocell. The photocell generates a signal that is fed back to control electronics which adjust the tube current to maintain a set laser output power. The laser should not be operated in Light Regulation Mode within approximately 5% of maximum current because the system needs adequate room to adjust the current for changing light output. It is

theoretically possible to operate in Light Regulation Mode with a current that is 0.1 A less than the system maximum current but the user must assume the risk that light regulation may go out of range if the system requires maximum current to maintain the requested light setting.

Special consideration should be taken when operating in Light Regulation Mode at the argon single line of 528.7 nm or the krypton single line of 647.1 nm. At either of these lines, maximum output power will typically occur at a current less than the maximum system current. Subsequent increases in current will not result in increases of output power. It is therefore recommended to operate in Light Regulation Mode at an output power less than 95% of the maximum output power if either of these lines is selected to avoid driving Light Regulation out of range.

Regulation of the output power of the Sabre may be in one of two modes: standard Light Regulation Mode (LT) or Reduced Bandwidth Light Regulation Mode (LT–). Maximum performance is provided by standard Light Regulation Mode and is the default mode that should be selected in almost all typical operating situations. When certain changes in system operating conditions are encountered, standard light regulation operation will be momentarily suspended and the system will automatically switch to Reduce Bandwidth Light Regulation. The output power will be temporarily modulated to calibrate the gain of the control loop. The system will then automatically return to standard Light Regulation. The duration of these events is on the order of two seconds. On a warmed-up, well-aligned system, assuming static operation, automatic gain re-calibration may not be required.

If the momentary modulation of the output power during calibration is undesirable for your particular operating conditions, it may be disabled. With the automatic gain calibration disabled, it is possible to operate for extended periods of time in standard Light Regulation. When conditions warrant a re-calibration of the gain, the system will not modulate the output power but will assume the Reduced Bandwidth Light Regulation Mode indefinitely. The user may also choose to operate specifically in Reduced Bandwidth Light Regulation but should be aware that PowerTrack is nonfunctional in this mode. A summary of the characteristics of the two Light Regulation Modes is shown in Table 5-6.

Table 5-6. Summary of Light Regulation Characteristics

Bandwidth	2 kHz ±10% (standard mode) Variable 10 Hz to 2 kHz (Reduced Bandwidth mode)
PowerTrack Compatibility	Yes (standard mode) No (Reduced Bandwidth mode)
Modulation signal required	Yes (standard mode) No (Reduced Bandwidth mode)
Modulation signal frequency	2 kHz
Modulation signal amplitude	5% to 10% of CW power level
Modulation signal duration	1 second (nominal)
Modulation signal latency period	1 second (nominal)

Automatic Gain Calibration

The Sabre ion laser standard Light Regulation Mode has been designed to suppress beam noise at frequencies up to 2 kHz. To achieve this suppression while maintaining stability of the light regulation servo loop, the gain of the servo loop must be set to its optimum value by the system software. This optimum gain value depends on the laser operating conditions—wavelength, output power, multiline vs. single line configuration — and is determined by means of an automatic gain calibration routine built into the system software. The automatic gain calibration routine is also referred to as Auto Light Cal or AutoLTCal. During execution of this routine, the output laser beam is modulated at 2 kHz for a period of approximately 1 second. The amplitude of the modulation is typically 5% of the total output power and in the worst case is approximately 10%. Gain calibration is performed automatically by the system when Auto Light Cal is enabled and any condition in Table 5-7 is true.

Note that the third condition in Table 5-7 states a tube current change of 20% will execute an automatic gain calibration. In very specific situations, this value, known as the percent change in tube current until re-calibration, may be changed through external computer control (Command: PctChgTilRecal = n).

Table 5-7. Conditions Requiring Automatic Gain Calibration

1	The operating mode of the laser is changed from current regulation to standard light regulation.
2	The light power setting is changed while the laser is in standard Light Regulation Mode.
3	The laser is operating in standard Light Regulation Mode and the tube current changes by 20% or more since the last execution of the automatic gain calibration routine.

The system default value of 20% is restored every time the system is requested to initiate the start delay sequence. For more information, refer the descriptions of this command and its respective query in Chapter Eleven, External Computer Control.

To enable (default) or disable automatic gain calibration from the remote control module, navigate the menu tree as shown in Figure 5-23. Use the up/down arrows to toggle between the "Yes" and "No" parameters and press SELECT to enter the change. Select "Yes" to enable automatic gain calibration. Select "No" to disable the automatic gain calibration. The setting will be stored in permanent memory Alternatively, use external computer control to set (Command: AutoLTCal = n) or acquire the status (Query: Print AutoLTCal).

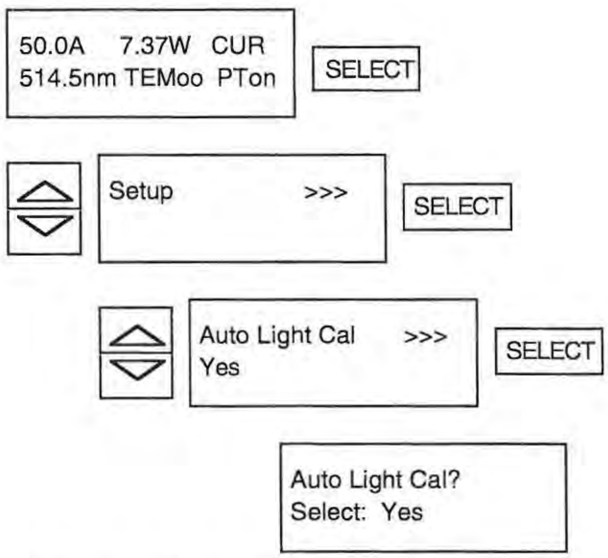


Figure 5-23. Auto Light Cal Menu Path

Error Detection During Automatic Gain Calibration

During execution of the automatic gain calibration routine, the system intercepts certain error conditions. In the event of such an error, the system automatically will enter the Reduced Bandwidth Light Regulation Mode and "LT–" will be displayed in the upper right hand corner of the "Default Menu". This change can occur even though the Auto Light Cal function is enabled. Should this event occur, toggle the LIGHT button to Current Regulation Mode then back to Light Regulation Mode to cause an automatic re-calibration. Refer to the "Light Reg Errors Menu" in the Light Regulation Diagostics Menu to determine if an error has occurred. All zero in that menu imply no errors.

Standard Light Regulation

Under certain conditions in standard Light Regulation Mode, the output laser beam is momentarily modulated by 5 to 10% at 2 kHz. If this poses a potential problem for your application, read this section carefully.

Standard Light Regulation provides a control loop that suppresses beam noise at frequencies up to 2 kHz. To maintain this loop bandwidth, the circuit will re-calibrate its loop gain whenever Auto Light Cal is enabled and any of the conditions in Table 5-7 occur. When the system is operating in standard Light Regulation Mode, "LT" will appear in the top right corner of the "Default Menu" on the remote control module and the LED above the LIGHT button will be steadily illuminated. When an automatic gain calibration occurs, the laser will momentarily switch to Reduced Bandwidth regulation and "LT–" will appear on the remote control module "Default Menu" while the output power is modulated. PowerTrack can be used simultaneously with standard light regulation. When the laser switches momentarily to Reduced Bandwidth Light Regulation during automatic gain calibration, PowerTrack will be momentarily parked and the LED above the PWR TRK button will be off.

In applications where the momentary modulation of the output power is undesirable, it is possible to disable the automatic gain calibration routine and still maintain standard light regulation. The following procedure places the laser in standard Light Regulation Mode but eliminates the possibility of the modulation signal appearing on the beam:

1. Ensure that the system is operating in the standard Light Regulation Mode and that automatic gain calibration is initially enabled (refer to Figure 5-23 with Auto Light Cal set to "Yes"). Alternatively, check the operating mode (Query: Print Mode) and the Auto Light Cal status (Query: Print AutoLTCal) through external computer control.

2. Disable automatic gain calibration (set the Auto Light Cal to "No") or use external computer control (Command: AutoLTCal = 0).

The laser will retain operation in the standard Light Regulation Mode until a gain calibration becomes necessary

due to the third condition listed in Table 5-7. The system will then switch to Reduced Bandwidth Light Regulation thus rendering PowerTrack inoperable. Note, however, that the third re-calibration condition under normal circumstances (laser system well aligned, warmed-up, and meeting specifications) should rarely occur. The system runs typically in light regulation for 24 hours without changing current more than a few tenths of an amp. The result, therefore, can be Light Regulation, with PowerTrack operable, and no calibration modulation.

A system initially operating in standard Light Regulation Mode with Auto Light Cal disabled will not retain operation in this mode if Light Regulation goes out of range or if the user toggles to current regulation and back to Light Regulation.

If automatic gain calibration is re-enabled while the system is operating in the standard Light Regulation Mode, then the re-calibration routine will immediately be executed and the system will assume the standard Light Regulation Mode.

Reduced Bandwidth Light Regulation

Reduced Bandwidth Light Regulation provides a control loop with a variable bandwidth that is greater than 10 Hz and less than 2 kHz. When the system is operating in Reduced Bandwidth Light Regulation Mode, "LT–" will appear in the top right corner of the "Default Menu" on the remote control module and the LED above the LIGHT button will be steadily illuminated. PowerTrack will be nonfunctional when the system is operating in the Reduced Bandwidth Light Regulation Mode. If PowerTrack is set to be On, it will be parked.

The system will be momentarily placed in Reduced Bandwidth Light Regulation during execution of the automatic gain calibration routine (refer to Table 5-7). If an error occurs during the re-calibration routine, the system will maintain Reduced Bandwidth Light Regulation Mode indefinitely. The system will also automatically switch from standard to Reduced Bandwidth Light Regulation Mode indefinitely if the third condition in Table 5-7 occurs while Auto Light Cal is disabled.

If desired, it is possible to force the system to operate in the Reduced Bandwidth light regulation using the following procedures:

1. Ensure that the system is operating in the Current Regulation Mode and that automatic gain calibration disabled (refer to Figure 5-23 with Auto Light Cal set to

"No"). Alternatively, check the operating mode (Query: Print Mode) and the Auto Light Cal status (Query: Print AutoLTCal) through external computer control.

2. Select light regulation by pressing the LIGHT button on the remote with the "Default Menu" displayed or use external computer control (Light = nn.nnnn).

If automatic gain calibration is enabled while the system is operating in the Reduced Bandwidth Light Regulation Mode, then the automatic gain calibration routine will immediately be executed and the system will assume the standard Light Regulation Mode.

Interrelationships of the Two Light Regulation Modes

Table 5-8 illustrates the interrelationships of the two Light Regulation Modes and acts to summarize the possible situations that can occur in system operation. The table is intended to be read from left to right to follow the system response to an action or event based on different initial conditions.

Table 5-8. Interrelationships of the Two Light Regulation Modes

Initial Auto Light Cal	Initial Mode	Action or Event	Gain Re-cal (Uses LT–)	Final Mode
On	CUR	Request Light Reg	Yes	LT
On	LT	Δ Current ≥ 20% or Request Δ Power	Yes	LT
On	LT	Δ Current ≥ 20% or Request Δ Power	Error Encountered	LT–
On	LT–	Request Δ Power	Yes	LT
On	LT–	Request Δ Power	Error Encountered	LT–
On	LT–	Δ Current ≥ 20%	No	LT–
On	LT	Turn Auto Light Cal Off	No	LT
Off	CUR	Request Light Reg	No	LT–
Off	LT–	Request Δ Power	No	LT–
Off	LT	Request Δ Power with Δ Current < 20%	No	LT
Off	LT	Δ Current ≥ 20%	No	LT–
Off	LT	Turn Auto Light Cal On	Yes	LT
Off	LT–	Turn Auto Light Cal On	Yes	LT

The first two columns indicate the initial conditions that exist simultaneously within the system. The initial status of the automatic gain calibration routine may be enabled (On) or disabled (Off). The initial operating mode can be current (CUR), standard light (LT), or Reduced Bandwidth light (LT–) regulation.

The third column indicates an action taken by the user or an event that occurs due to system operation. The user may engage light regulation or request a change in the light power setting (Δ Power) or change the state of the Auto Light Cal. An event may occur that requires the system to change the tube current (Δ Current) in order to maintain the light setting.

The fourth column indicates whether or not the automatic gain calibration routine is executed (Yes or No) or if an error is encountered during the execution of the routine. While the routine is executing, the system will temporarily be placed in the Reduced Bandwidth Light Regulation Mode (Uses LT–).

The fifth column indicates the regulation mode that the system will finally assume.

For example, the second entry in Table 5-8 indicates that the system initially was operating in standard Light Regulation Mode with automatic gain calibration enabled. The user changed the light power setting or the system misaligned such that the change in current since the last gain calibration exceeded 20%. In response, the system re-calibrates the gain of the control loop, temporarily places the system in (LT–) during the routine, and then assumes standard light regulation as the final system operating mode.

Note that the system default value of 20% presented in the Table 5-8 that indicates the percent change in tube current until re-calibration may be changed through external computer control (Command: PctChgTilRecal = n).

Light Regulation Out of Range

When Light Regulation Mode is requested but out of range, the LED above the LIGHT button will blink. The system will temporarily operate in Current Regulation Mode and the upper right hand corner of the "Default Menu" will display "CUR". Light regulation is considered to be out of range if the current required by the system to achieve the light setting is not within the system's minimum to maximum current range. The minimum current is typically 10 A and may be acquired through external computer control (Query: Print Minimum Current). The maximum current is system type dependent. The maximum system current may be acquired from the

remote by navigating to the "Passbank Status Menu" as will be described in a subsequent section: REMOTE STANDARD MENUS: STATUS MENUS. Alternatively, use external computer control (Query: Print Maximum Current).

The most commonly encountered example of the out of range situation is a system operating properly in Light Regulation Mode where the intracavity shutter is suddenly closed interrupting the lasing beam. The system would try to achieve the requested light setting but would go out of range by operating at maximum current in Current Regulation Mode. Another example of light regulation going out of range is a request for a light setting that is higher than can possibly be attained by the system. In this case the system would go to Current Regulation Mode at maximum current in an attempt to achieve the light setting. The converse to this situation is a request for a light setting that is lower than that produced by the system operating at minimum tube current. In this case the system would maintain current regulation at minimum current and light regulation would indicate that it went out of range.

Situations where Light Regulation Mode goes out of range may be remedied in several ways. An immediate solution would be to cancel Light Regulation Mode and request the system to operate in Current Regulation Mode. To accomplish this from remote, press the up or down arrow to definitively put the system into Current Regulation Mode at the current setting displayed on the remote. Alternatively, use external computer control to request Current Regulation Mode (Command: Current = nn.nn).

If light regulation goes out of range and sufficient lasing is restored, for example by re-opening the intracavity shutter or execution of the TUNE procedure, the system can re-establish Light Regulation Mode automatically. In order to automatically switch back to Light Regulation Mode, the system requires 5% more actual power than the requested light setting to ensure enough current margin and to prevent oscillation. If a sufficient actual power is not being produced for automatic switching to occur, press the LIGHT button on the remote while the LED above it is flashing to request the system to operate in light regulation at the previously requested light setting. Alternatively, use external computer control (Command: Light = nn.nnnn) to set the light level at a value less than or equal to that displayed in the default menu.

If light regulation can not be restored by any of the methods described above, it may be necessary to enter Current

Regulation Mode using the up/down arrows of the remote with the "Default Menu" displayed. Scroll the current until the light power is approximately at the desired level and engage light regulation by pressing the LIGHT button. The exact desired light setting may then be input using the up/down arrows.

If light regulation goes out of range at maximum current and can not be restored, it may be necessary to execute the TUNE procedure, check the cleanliness of the optics, or perform some cavity alignments. If the output power is below specification, refer to Chapter Nine, Troubleshooting, for more information.

Autofill

All ion laser plasma tubes can suffer a slow loss of gas pressure during operation and must include a means of maintaining the optimum pressure over the lifetime of the tube. The autofill circuitry in the Sabre laser head senses a drop in gas pressure through tube voltage measurement at a given tube current. The fill mechanism is automatically activated to replenish the gas inside the plasma tube ensuring that the tube pressure will be maintained without attention from the system operator.

In order to assure optimum laser performance at any current setting throughout the life of the plasma tube, the autofill circuitry will not give gas fills when the tube operating current is below the autofill threshold. The default threshold current set for the Sabre, at keyswitch ON or at the onset of tube ionization, is 20 Amps.

The value of the autofill threshold current can be changed by the operator using external computer control (Command: NoFill Range = n) when special situations require it. In general, the effects of the autofill sequence on system performance are minimal and the default value should be maintained. If the autofill threshold current is changed, however, all references to 20 A in the following autofill sections should be changed to the value set by the user.

The difference between the measured tube voltage and the voltage at which the tube will need a fill is known as the autofill delta. The autofill system strives to maintain a positive delta. To determine the autofill delta from the remote, navigate the menu tree as shown in Figure 5-24. Alternatively, use external computer control (Query: Print

Autofill Delta). In the example shown, a positive 1.7 V delta exists.

The autofill sequence is activated whenever the three following conditions are all true for a 5 minute period:

1. A negative autofill delta is continuously measured.

2. The tube current is greater than or equal to the autofill threshold current (20 Amps).

3. Changes in the tube current are less than 1 Amp.

The autofill sequence takes one minute per fill. During each fill sequence, two "clicks" in the laser head, separated by 30 seconds, may be audible when the autofill solenoids open the ready and fill valves. The five minute measurement period and the one minute fill sequence continue until a positive delta is measured.

To protect itself from operating with too low of a pressure, the system will shut down with a "Low Pressure" fault if a delta of -5 V is measured while operating below the autofill threshold current or if a delta of -7 V is measured after giving three fills while operating above or equal to the threshold current. For more information, refer to Chapter Nine, Troubleshooting.

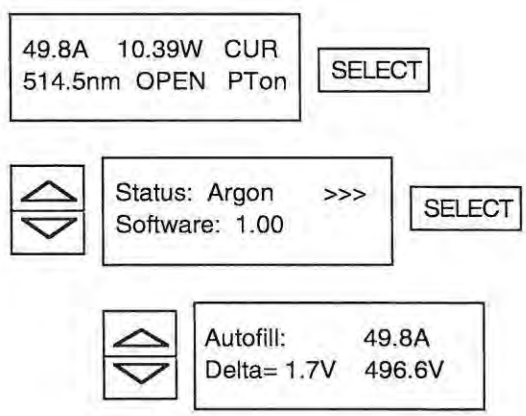


Figure 5-24. Autofill Menu Path

Automatic Shutdown

An automatic system shutdown will occur if conditions prevent a fill from being taken for 100 hours. If a negative delta exists for 5 minutes and either the second or third condition presented in the previous section is not true, then the system decrements a 100 hour countdown to perform an

automatic shutdown. In other words, the 100 hour countdown is active with a negative delta below 20 A or with a negative delta and a greatly changing tube current above 20 A. The countdown is continuously decremented as required and is not reset to 100 hours if the system is shut down manually. The countdown will be reset to 100 hours only if a positive delta is measured.

The time remaining in the automatic shutdown may be accessed through external computer control (Queries: Print Autofill Hours or Print HrsTilShutdown). To access the status of the autofill automatic shutdown from the remote, navigate the menu tree as shown in Figure 5-25. In the example shown in the figure, the lowest menu level displays "Autofill OK" indicating that the time remaining in the automatic shutdown is greater than 90 hours. This is the normal situation encountered in practice.

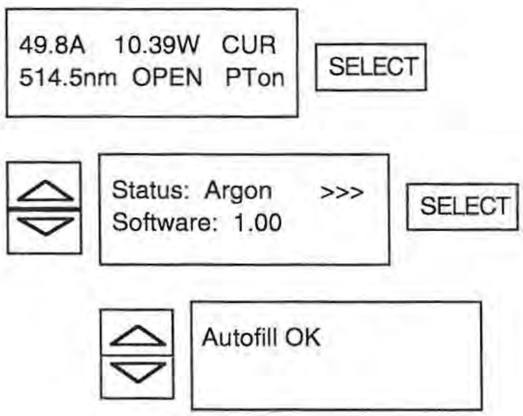


Figure 5-25. Autofill Status Menu Path

When the time remaining until an automatic shutdown is 90 hours or less, the lowest menu level of Figure 5-25 will be changed to that shown in Figure 5-26 with the appropriate countdown time displayed.

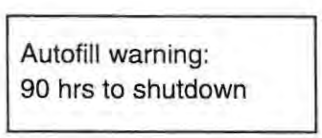


Figure 5-26. Automatic Shutdown Countdown in Autofill Status Menu

When the time remaining in the countdown reaches 10 hours, the system warning message, shown in Figure 5-27, will be displayed on the remote irregardless of the current menu level. To clear the warning message from the remote display, use the EXIT or SELECT buttons. It is recommended to use the EXIT button when displaying lower menu levels to avoid inadvertently selecting an undesirable system operating parameter. Use the SELECT button when displaying the "Default Menu". The warning message with the appropriate countdown time will be displayed each time the system is restarted if conditions warrant continuation of the countdown.

The automatic shutdown warning message at 10 hours or less is not available through external computer control. If operating the system in this no-fill regime, the reported time remaining should be periodically monitored (Queries: Print Autofill Hours or Print HrsTilShutdown) to anticipate the possibility of an impending shut down. Preferably, refer to the next section, Avoiding an Automatic Shutdown, to maintain a positive delta.

Autofill warning:
10 hrs to shutdown

Figure 5-27. Automatic Shutdown Warning Display

Upon completion of the 100 hour countdown as the time remaining reaches 0 hours, the system will automatically shut down. The "Default Menu" on the remote will replaced by the fault message shown in Figure 5-28. Alternatively, the fault string "Low I Shutdown Start at 30 Amps" can be accessed by external computer control (Query: Print Faults). If the laser system shuts down for a reason other than Low I Shutdown, the "Default Menu" will display the appropriate fault message (Low Pressure, for example). For more information on system faults, refer to Chapter Nine, Troubleshooting.

Low I Shutdown
Start at 30 Amps

Figure 5-28. Automatic Shutdown Fault Display

To restart the laser using the remote, press the ON/OFF button and adjust the tube current setting to 30 Amps while in the start delay sequence. Alternatively, turn the keyswitch OFF and then ON to clear the display. Adjust the current setting to 30 Amps and restart the system. External computer control may also be used to set the current (Command: Current = 30) and restart the system (Command: Laser = 1). Allow the system to run at 30 Amps while the fill system brings the laser to the required operating voltage. Depending on the tube voltage, this process may require 6 to 48 minutes. The countdown will be reset to 100 hours only when a positive delta is measured.

Avoiding an Automatic Shutdown

To avoid the inconvenience of an automatic shutdown, operate the system at a constant current setting above the autofill threshold, 20 Amps. Maintain the constant current for approximately 45 minutes to allow the fill system to adjust the tube voltage for a positive delta. This procedure should be repeated after every two days of system operation.

Remote Standard Menus

The remote control module is capable of displaying a standard set of menus and an extended set of menus. Switch 8 on the DIP switch on the rear of the power supply labeled, MT TALK ADDRESS, determines the number of menus available on the remote control module. In the down (OFF) position, only the standard menus are accessible. In the up (ON) position, the extended menus will be accessible. The standard set of menus is always displayed in either case and consists of the "Status Menu", "Aperture Menu", "Wavelength Menu", "Etalon Menu", "Memory Programming Menu", "Magnet Menu" (for krypton Sabre), and their related lower menu levels. Access to these menus from the "Default Menu" is possible by pressing SELECT and using the up/down arrows to navigate to the desired menu. The complete menu tree is shown in Figure 5-2.

Status Menu

The "Status Menu" and its related lower menu level display information concerning the status of some of the system operating parameters. Each menu display will be described and the related queries accessible through external computer control will be listed.

Status Menus

Status: Argon >>> Software: 1.00	The first line indicates the tube gas type (Query: Print Gas). The second line indicates the version number of the power supply software (Query: Print Software).
Tube Hours: 1424 Head Hours: 1424	The first line indicates the number of ionized operating hours on the current plasma tube (Query: Print Tube Hours). The second line indicates the number of ionized operating hours on the system head (Query: Print Head Hours).
Water Flow: 6.0 GPM Inlet Temp: 30.1 °C	The first line indicates the water flow rate in gallons per minute (Query: Print Water Flow). The second line indicates the power supply inlet water temperature in degrees Celsius (Query: Print Water Temperature).
Water Resistivity 320 kΩ -cm	Indicates the power supply inlet water resistivity in kΩ•cm (Query: Print Water Resistivity)
Cathode I: 38.3 A Magnet I: 14.2 A	The first line indicates the measured cathode current in AC amps rms (Query: Print Cathode Current). The second line indicates the measured magnet current in DC amps (Query: Print Magnet Current).
Autofill: 50.5A Delta=4.5V 497.3V	Displays the system parameters relative to the autofill system. The first line indicates the DC tube current (Query: Print Current). The first field in the second line indicates the autofill delta which is the actual DC tube voltage minus the voltage at which the tube will need a fill (Query: Print Autofill Delta). The second field in the second line indicates the measured DC tube voltage (Query: Print Tube Voltage).
Autofill OK	Displays the autofill system status. "Autofill OK" indicates that greater than 90 hours remain in the automatic shutdown countdown. When the time remaining is less that 90 hours, the countdown time will be displayed. For more information, refer to the previous section and related subsections: AUTOFILL.

Status Menus

(Continued)

The autofill circuitry will only engage if the system is operating at the same current setting for five minutes at a set current or power level. If your application requires frequent changes in current, run the system at full current for fifteen minutes at least once a day. This fixed current run will allow the autofill circuitry to bring the plasma tube to the correct pressure for tube operation.

Failure to maintain correct tube gas pressure will cause an under voltage fault which will shut down the system. In addition, running the plasma tube at lower than normal gas pressure for prolonged periods is harmful to the tube.

```
Passbank:
V=138.4     MaxI=65A
```

The first field of the second line indicates the total DC voltage across the passbank at the present tube current (Query: Print Passbank Voltage).

The second field of the second line indicate the maximum DC current deliverable by the passbank of this power supply (Query: Print Maximum Current). If this number is the same for two Sabre Ion Lasers, then the power supplies are interchangeable.

```
Tube:       P=12.053W
I=50.5A     V=497.3V
```

Displays tube operating parameters. The first line indicates the measured output power (Query: Print Light).

The first field of the second line indicates the measured DC tube current (Query: Print Current).

The second field of the second line indicates the measured DC tube voltage (Query: Print Tube Voltage).

```
PowerTrack On
PTA: 511   PTB: 532
```

The top line indicates the current PowerTrack status (Query: Print PowerTrack).

The second line indicates the relative readings of the PowerTrack DACs for A (vertical) and B (horizontal). The range is 0 to 1023. (Queries: Print PTDACA and Print PTDACB). For more information, refer to the previous section and related sub-sections titled: LASER HEAD AND AUTOMATED FEATURES: PowerTrack.

Aperture Menu

```
Aperture        >>>
Manual  AP#18
```

The "Aperture Menu" and its related lower menu level are used to display the current aperture setting, the aperture status, aperture errors, and to select a different aperture setting.

The first field of the second line will indicate whether or not the system is operating with a single transverse mode by displaying "TEMoo" in place of the "Manual" string.

More information on this menu and its related lower menu level has been described in a previous section and related sub-section titled: LASER HEAD AND AUTOMATED FEATURES: Automatic Aperture and TEM_{00} Detector.

Wavelength Menu

```
Wavelength      >>>
488.0 nm
```

The "Wavelength Menu" and its related lower menu levels are used to display the current wavelength setting and to select a different wavelength. Selections in the lower menu levels also tell the system which rear mirror holder is installed and which optic set is physically installed.

More information concerning single line wavelength changes within a given optic set has been described in a previous section titled: LASER HEAD AND AUTOMATED FEATURES: Motorized Rear Mirror Plate: Changing Single Line Wavelengths.

Information concerning multiline/single line conversions and changing optic sets will be described in Chapter Seven, Optics and Alignment Procedures.

Etalon Menu

```
Etalon: NuTrack   >>>
T=52.706 Z DAC=2132
```

The "Etalon Menu" is used to display the current etalon mode, etalon set temperature, and Z-axis DAC value. Its related lower menu levels are used to select different etalon modes or manual controls.

Information concerning this portion of the menu tree will be presented in Chapter Eight, Single-Frequency Operation.

Memory Programming Menu

Memory	>>>
Programming	

The "Memory Programming Menu" and its related lower menu level are used to store system operating parameters in memory levels 1 and 2.

A complete discussion of memory programming and recall has been presented in the previous section and relate sub-sections: REMOTE CONTROL MODULE: Pushbutton Controls - Dedicated Buttons: MEMORY.

Magnet Menu

Magnet	>>>
Low field	

The "Magnet Menu" and its related lower menu level are used to display the current magnetic field and to select a different field setting. It appears only on krypton Sabre systems.

The second line of the upper menu level indicates the current magnetic field as sensed by the power supply hardware (Query: Print Field).

The associated lower menu level is accessible only when the system is off. The second line of the lower menu level indicates the set field. Use the up/down arrows to display the desired "Low field" or "High field" value and press SELECT. Alternatively, use external computer control to set the field (Command: Field = n) or to acquire the set value (Query: Print Set Field).

Select "High field" when operating with violet and UV wavelengths (≤ 468.0 nm). Select "Low field" for all other wavelengths.

Remote Extended Menus

The remote control module is capable of displaying a standard set of menus and an extended set of menus. Switch 8 on the DIP switch on the rear of the power supply labeled, MT TALK ADDRESS, determines the number of menus available on the remote control module. In the down (OFF) position, only the standard menus are accessible. In the up (ON) position, the extended menus will be accessible. The standard set of menus described in the previous section, is always displayed in either case. The extended set of menus includes the "Diagnostic Menu", "Setup Menu", "Shutter Auto Exposure Menu" and their related lower menu levels. Access

to these menus from the "Default Menu" is possible by pressing SELECT and using the up/down arrows to navigate to the desired menu. The complete menu tree is shown in Figure 5-2.

Diagnostics Menu

The "Diagnostics Menu" and its related lower menu levels, as shown in Figure 5-29, are used to obtain detailed information concerning system status and operating parameters. Control of certain special features is also accessible in the "Diagnostics Menu" lower levels. The detailed information can only be interpreted by Coherent Technical Support and Field Service Engineers. The information that they present may be useful in troubleshooting problems by telephone or on-site. Brief descriptions of the contents of the lower menu levels will be presented in the following sections. The related queries accessible through external computer control will be listed.

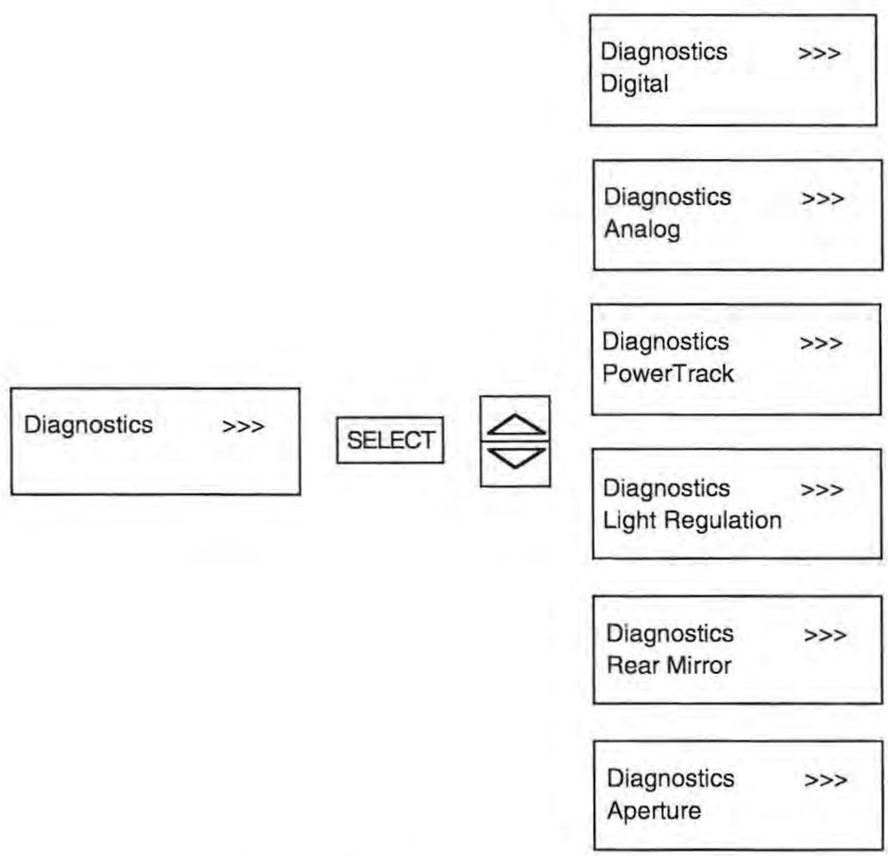


Figure 5-29. Diagnostics Menus

Diagnostics Menu: Digital

Resets	P/S: 0
Rem: 0	Head: 0

The first line indicates the number of power supply CPU resets (Query: Print Resets).

The first field of the second line indicates the number of remote CPU resets.

The second field of the second line indicates the number of head CPU resets (Query: Print Head Resets).

Head Software
Version 1.00

Indicates the version number of the head software (Query: Print Head Software).

S:15621	Sync:0
Re:2	Err:0

Indicates tallies of commands sent by the power supply to the head.

The first field of the first line indicates the number of commands sent (Query: Print Head Sends).

The second field of the first line indicates the number of synchronization errors encountered with head and power supply communication (Query: Print Head Sync).

The first field of the second line indicates the number of retries of commands (Query: Print Head Retries).

The second field of the second line indicates the number of errors (Query: Print Head Errors). An error occurs after 3 retries, of the same command, fail.

Head Msg:

The second line indicates the last text message sent by the head to the power supply (Query: Print Head Message).

P/S Comm	Err:0
S:1524	Re:0

Indicates tallies of asynchronous status change messages sent by the power supply to the remote.

The first line indicates the number of errors (Query: Print Remote Errors). An error occurs after 2 retries, of the same message, fail.

The first field of the second line indicates the number of messages sent (Query: Print Remote Sends).

The second field of the second line indicates the number of retries of messages (Query: Print Remote Retries).

Rem Comm	Err:0
S:1237	Re:0

Indicates tallies of commands sent by the remote to the power supply.

The first line indicates the number of errors. An error occurs after 2 retries, of the same command, fail.

The first field of the second line indicates the number of commands sent.

The second field of the second line indicates the number of retries of commands.

Diagnostics Menu: Analog

Autofill Count: 134 Delta=4.5 I=50.5	The top line indicates the total number of gas fills taken by the plasma tube (Query: Print Autofill Count). The first field of the second line indicates the autofill delta in DC volts (Query: Print Autofill Delta). The second field of the second line indicates the measured tube current in DC amps (Query: Print Current).
Icath Vcath Setpoint 32.7 3.25 135	The first field indicates the raw (uncalibrated) value of the cathode current in AC amps rms (Query: Print Raw Cathode Current). The second field indicates the measured cathode voltage in AC volts rms (Query: Print Cathode Voltage). The third field indicates the value of the cathode setpoint (Query: Print Cathode Setpoint).
Fan Speed 6	Indicates a relative value of the power supply fan speed (Query: Print Fan).
RMS Noise: 0.124%	Indicates the measured optical rms noise in percent with a bandwidth of 10 Hz to 200 kHz (Query: Print Noise).
P/S +12V: +11.89 P/S -12V: -11.90	Indicates the measured voltages of the +12 V and -12 V DC supplies on the power supply controller PCB (Queries: Print Positive Voltage and Print Negative Voltage).
Head +12V: +11.95 Head -12V: -11.88	Indicates the measured voltages of the +12 V and -12 V DC supplies on the head PCB (Queries: Print Head Positive Voltage and Print Head Negative Voltage).

Diagnostics Menu: Analog

(Continued)

```
Ripple Current
6.2A          Max:12.6
```

Indicates the ripple current in amps supplied by the power supply's filter capacitors to suppress line noise.

The first field indicates the present value (Query: Print Ripple Current).

The second field indicates the maximum value detected (Query: Print Maximum Ripple Current).

```
Heat Exchanger    >>>
ON
```

This menu level indicates the current status of the manual heat exchanger control (Query: Print Water).

Its lower menu level exists only when the system is de-ionized. The lower menu level is used to select the state of the manual heat exchanger control (Command: Water = n)

A complete discussion of these menus has been presented in the previous section: SABRE HEAT EXCHANGER: Manual Heat Exchanger Control.

Diagnostics Menu: PowerTrack

PTgain	Max	Filter
24	28	27

Indicates relative parameters associated with the PowerTrack servo loop.

The first field indicates the present PowerTrack gain (Query: Print PT Gain).

The second field indicates the maximum PowerTrack gain (Query: Print Maximum PT Gain).

The third field indicates the present PowerTrack filter which reflects the amplitude of the PowerTrack error signal (Query: Print PT Filter).

PowerTrack Cal	>>>
PowerTrac On	

The lower menu level associated with this menu is used to perform a PowerTrack calibration.

A complete discussion of this procedure has been presented in the previous section: LASER HEAD AND AUTOMATED FEATURES: PowerTrack: PowerTrack Calibration.

PTDACA		>>>
127	508	556

PTDACB		>>>
136	544	556

The remaining two menus in the "PowerTrack Diagnostics Menu" are used for manual control of the PowerTrack actuators providing for manual control of the tilt of the output coupler in the vertical (A) and horizontal (B) rotational axes. PowerTrack must be turned Off to allow manual control. From the "Default Menu", navigate the menu tree as shown in Figure 5-30. The example shown in the figure would control the PowerTrack DAC A. A similar path would be required to control the PowerTrack DAC B.

The lowest two menu levels shown in Figure 5-30 each contain three fields in their second lines which display the same information. The first field is the setpoint for the PowerTrack DAC A. It has a range of 0 to 255. When in the lowest menu level, the up/down arrows may be used to change this value. Press SELECT to initiate the change of the output coupler tilt. Alternatively, use external computer control to set (Commands: PTDACA = n or PTDACB = n) or acquire these values (Queries: Print Set PTDACA or Print Set PTDACB). Note: When operating in single-frequency the effectiveness of changing the PowerTrack setpoints may be inhibited by the current ZDAC value. For more information, refer to Chapter Eight, Single-Frequency Operation.

The second field indicates the measured reading of the PowerTrack DACs A. This value has a range of 0 to 1023 and is the same that is found in the "PowerTrack Status Menu". The relationship between read and set DACs is approximately 4 to 1. The read value may be acquired through external computer control (Queries: Print PTDACA or Print PTDACB). The third field indicates a relative value of the photocell signal measured in the power supply. It assumes the same value as the Photocell 1 value presented in the "Light Regulation Diagnostics Menu" described in the next section. This value may be acquired through external computer control (Query: Print Photocell 1).

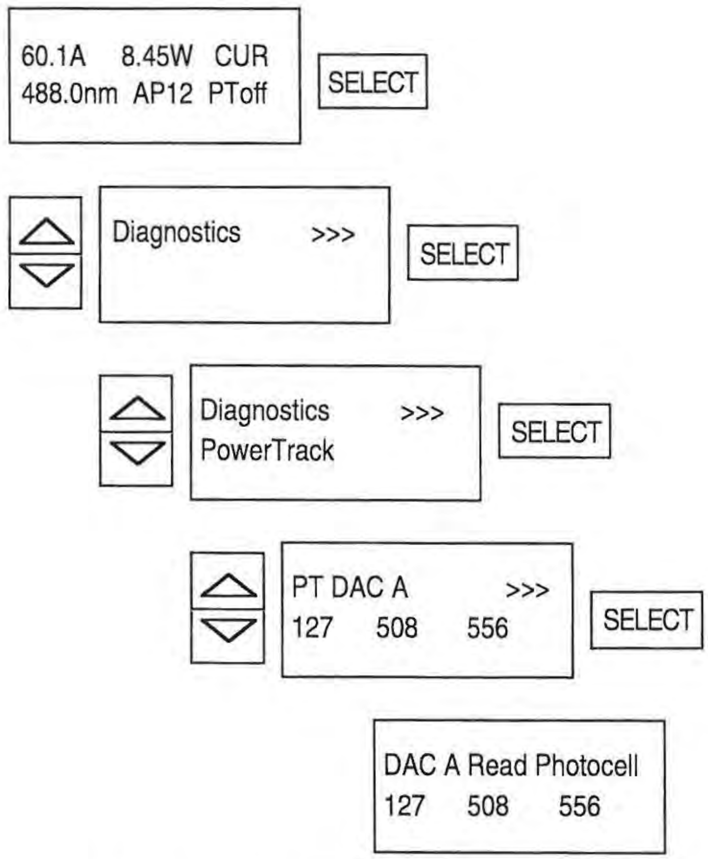


Figure 5-30. Manual PowerTrack Control Menu Path

Diagnostics Menu: Light Regulation

Photocell Inputs: 1=555 2=276 3=567

Indicates the relative photocell values at three points between the photocell and the power supply microprocessor.

The first field indicates the value just before input to the microprocessor (Query: Print Photocell 1).

The second field indicates the value just after input to the power supply controller PCB (Query: Print Photocell 2).

The third field indicates the vale just before output from the head PCB (Query: Print Photocell 3).

Photocell Temp 51.5 °C

Indicates the photocell temperature in degrees Celsius (Query: Print Photocell Temperature).

PC Monitor Flag? >>> 1

This menu indicates the status of the photocell automatic gain switching of the amplifiers in the head (Query: Print Photocell Monitor). The defaults are: enabled during Current Regulation Mode and disabled during Light Regulation Mode.

The related lower menu level allows selection of the parameter to enable (1) or disable (0) the photocell automatic gain switching (Command: Photocell Monitor = n).

Photocell Gain >>> 2

This menu indicates the gain setting of the photocell amplifiers in the head (Query: Print Photocell Gain).

The related lower menu level allows selection of the parameter (Command: Photocell Gain = n). Manual selection is only possible when Photocell Monitor Flag is disabled.

n = 1, 2, 4, 8, 16, 32, 64, 128, 512

Diagnostics Menu: Light Regulation

(Continued)

Light Reg Errors 0 0 0 0 0 0 0 0

Indicates light regulation (LR) errors (Query: Print LR Errors). A reading of all zeros means that there are no faults.

The light regulation error bits as displayed from right to left represent the least significant to most significant bits. The explanations of the corresponding decimal equivalents of each bit are as follows:

1 = Inner Loop Error: hardware error of LR control circuit. (Far right of display).

2 = Bad LR Setting Error: software LR setup error.

4 = Scale Factor Error: bad or non-existent photocell or set light DAC calibration for present wavelength.

8 = No Head Response Error: head communication did not acknowledge requested photocell gain.

16 = Not Converging Error: LR calibration algorithm cannot converge to proper gain setting for Standard light Regulation.

32 = Low Gain Error: LR calibration algorithm cannot set to high enough gain setting for Standard Light Regulation because power vs. current gain is too low for this wavelength at this current.

64 = Excess Gain Error: LR calibration algorithm cannot set to low enough gain setting for Standard Light Regulation because power vs. current gain is too high for this wavelength at this current.

128 = Open Loop Error: hardware error of LR control circuit, LR calibration could not measure 2 kHz calibration signal. (Far left of display).

Light Reg Setpoint 0xb1a

Indicates the hex value of the light regulation DAC setpoing (Query: Print LR Setpoint).

Light Reg Gain 0xff

Indicates the hex value of the light regulation gain (Query: Print LR Gain).

Diagnostics Menu: Rear Mirror

The lower levels of the"Diagnostics: Rear Mirror Menu" are used in conjunction with "manual" control of the motorized rear mirror plate. Note: Use of these menus can inhibit proper execution of integrated routines utilized by the motorized rear mirror plate and may affect system performance. For more information, refer to Chapter Nine, Troubleshooting, in the section titled: "MANUAL" CONTROL OF SYSTEM MOTORS: Motorized Rear Mirror Plate.

Horizontal Motor >>> Go steps	Associated lower level allows "manual" control of the rear mirror plate horizontal stepper motor.
Vertical Motor >>> Go steps	Associated lower level allows "manual" control of the rear mirror plate vertical stepper motor.
Goto cal position >>>	Associated lower levels are used to "manually" orient the mirror plate to known calibrated argon positions for the multiline, VIS single line, UV single line rear mirror holders, and D/SUV single line rear mirror holders or the krypton positions for the multiline, VIS/IR single line, and UV single line rear mirror holders.
Search rear plate >>>	Performs a localized search to establish and optimize lasing without going to the home position first.

Diagnostics Menu: Aperture

The lower levels of the"Diagnostics: Aperture Menu" are used in conjunction with "manual" control of the automatic aperture. Note: Use of these menus can inhibit proper execution of integrated routines utilized by the automatic aperture and may affect system performance. For more information, refer to Chapter Nine, Troubleshooting, in the section titled: "MANUAL" CONTROL OF SYSTEM MOTORS: Automatic Aperture Motor.

Aperture motor >>>
Go steps

Associated lower level allows "manual" control of the automatic aperture motor.

Setup

The three lower menus associated with the "Setup Menu" are system operating parameters that probably will have to be changed infrequently.

Baud rate >>>
19200

This menu indicates the current RS-233/422 baud rate (Query: Print Baudrate).

The associated lower menu level allows selection of the baud rate (Command: Baudrate = n).

Valid baud rates are: 110, 300, 1200, 2400, 4800, 9600, and 19200.

Auto Light Cal >>>
Yes

This menu indicates the status of the automatic gain calibration of the Light Regulation Mode (Query: Print AutoLTCal).

The associated lower menu level allows the user to enable (Yes) or disable (No) automatic gain calibration (Command: AutoLTCal = n).

A complete discussion of this routine has been presented in the previous section and related sub-sections: LIGHT REGULATION MODE.

Auto Shutter >>>
Yes

This menu indicates the status of the Auto Shutter feature (Query: Print Auto Shutter).

The associated lower menu level allows the user to enable (Yes) or disable (No) the Auto Shutter feature (Command: Auto Shutter = n).

A complete discussion of this feature has been presented in the previous section: LASER HEAD AND AUTOMATED FEATURES: Auto Shutter.

Shutter Auto Exposure

Shutter >>> Auto Exposure

The associated lower menu level allows selection of an exposure time for automatic external shutter operation.

A complete discussion of this feature has been presented in the previous section: LASER HEAD AND AUTOMATED FEATURES: Auto Exposure.

Operator's Manual

Chapter Six
Daily Operation

COHERENT

Introduction

This chapter provides general information relating to daily operation of the Sabre. Recommended operating current ranges, comments on the autofill system, and daily turn on and shut down procedures for multiline/single line operation are presented. Refer to Chapter Eight, Single-Frequency Operation for procedures concerning that cavity configuration.

For safety considerations, read Chapter Three, Laser Safety, before operating the laser system.

Recommended Tube Currents

INNOVA ion laser systems are capable of operating from lasing threshold to the maximum available output power as determined by the power supply. To maximize plasma tube lifetime, it is recommended to operate at specified output power levels. This ensures that the plasma tube is being used in the manner for which it was designed. Different operating wavelengths will require different plasma tube currents. For example, UV lines are much lower gain than visible lines and will therefore require higher current levels to produce specified output powers.

The available plasma tube current assumes a broad range as shown in Figure 6-1. There is a current range in which the plasma tube should be operated to maximize tube lifetime.

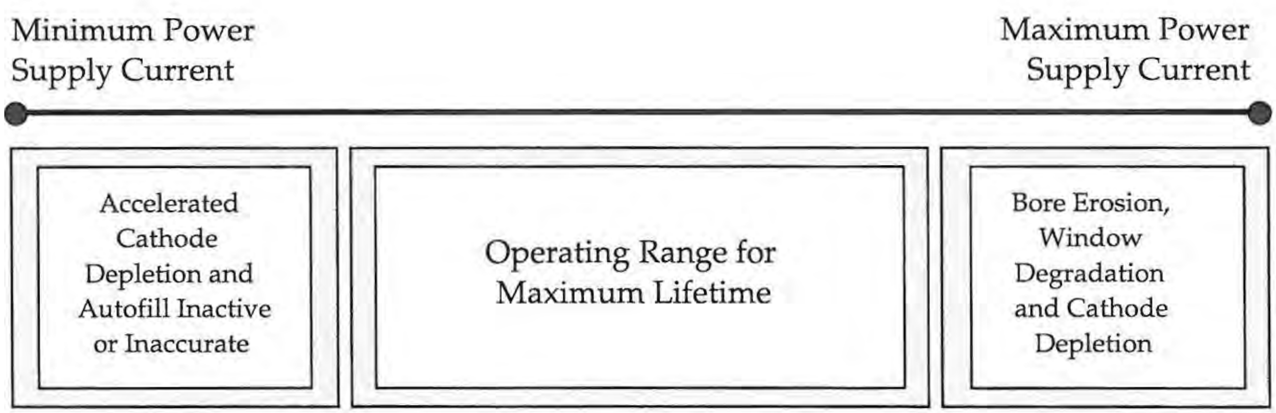


Figure 6-1. Plasma Tube Current Operating Range

Operating the plasma tube at high currents will increase the cathode temperature and evaporation rate of electron donor material resulting in cathode depletion. Higher discharge currents can increase the rate of bore erosion resulting in the reduction of plasma density and temperature along the optic axis and therefore produce lower output powers. Bore erosion also decreases the gas pressure for a given tube voltage which is detrimental to the output power of some lines but beneficial to others. Higher tube currents generally produce higher output powers and a finite amount of optical absorption in the intracavity Brewster window(s) can cause transverse mode degradation and power loss. These effects are stronger for UV lines, as they are more sensitive to increased optical loss in the cavity. Increased window degradation, therefore, is associated with system operation at higher tube currents.

Operating the plasma tube at low currents decreases the gas pressure at the cathode and can induce accelerated cathode depletion. Proper tube pressure is maintained by the autofill system as described in Chapter Five, System Description and Conrol, in the section and related sub-sections titled: AUTOFILL. The behavior of the V-I curve (refer to Chapter Ten, Theory of Operation), on which the autofill algorithm is based, can change during the lifetime of the plasma tube making the autofill system inaccurate at low tube currents. For this reason, the Sabre automatically disables the autofill system below 20 A and prolonged operation below that level is not recommended.

Start-Up Procedure

Refer to the first time start-up procedure section of Chapter Four, Utility Requirements and System Installation, when starting the laser for the first time or after the laser has been moved. Refer to Chapter Nine, Troubleshooting, to resolve any faults or problems encountered.

1. Enable the primary supply of facility cooling water to the Sabre heat exchanger. Note that the Temperature Regulation Valve of the primary loop may inhibit flow until the system is ionized.

2. Ensure that the keyswitch, located on the front panel of the power supply, is in the OFF position. Turn on the facility circuit breaker to establish main line power.

3. Turn the keyswitch to the ON position. Wait for the remote control module to power up. The two indicator LEDs on the front panel of the power supply should be on.

4. If sensitive optical elements exist in the output beam path and Auto Shutter is disabled, close the external shutter to protect from a possible momentary output power surge at the onset of ionization. (Press SHUTTER button such that LED above it is off.)

5. Press the ON/OFF button on the remote to initiate the start delay sequence. The following will occur:

   - The heat exchanger will turn on and circulate cooling water by application of power to its pump.
   - The LASER EMISSION indicators on the front of the laser head and the remote control module will be illuminated.
   - The external shutter will be closed.
   - Power will be applied to the cathode circuitry.
   - The "Default Menu" of the remote control module will display a 75 second Start Delay countdown.
   - With 50 seconds remaining in the countdown, the power supply main contactor will engage providing tube voltage and magnet current. The contactor makes a distinctive sound which can be easily heard except in unusually noisy environments.
   - At zero seconds, the starter will fire resulting in ionization of the plasma tube.
   - Lasing can occur immediately upon tube ionization if the intracavity shutter is open.
   - The external shutter will open if the user had requested it.

6. If lasing does not occur when the tube ionizes, check that the intracavity beam shutter, positioned at the rear of the laser head, is open. If open, re-enter the desired wavelength using the "Wavelength Menu" or initiate the TUNE procedure. Either selection will initiate a search procedure to establish lasing.

7. After lasing has been achieved, use the LIGHT button on the remote to select either Light or Current Regulation Mode. Use the up/down arrows to select the desired light or current setting. Select the desired aperture position using the "Aperture Menu".

The autofill circuitry will only engage if the system is operating at the same current setting for five minutes. If your application requires frequent changes in current or power level, run the system for fifteen minutes at a fixed current above 20 Amps at least once per day. Operating at a fixed current will allow the autofill circuitry to maintain the nominal pressure for system operation.

Failure to maintain correct tube gas pressure might cause a "Low Pressure" fault which will shut down the system. In addition, running the plasma tube substantially below normal gas pressure for prolonged periods will shorten tube lifetime.

---

8. Open the external shutter, if applicable, to allow the output beam to exit the laser head. (Press SHUTTER button such that LED above it is on.)

Shut-Down Procedure

1. Press the ON/OFF button on the remote control module to shut the system down. This will disengage the power supply main contactor and de-ionize the plasma tube.
2. Turn the keyswitch, located on the front panel of the power supply, to the OFF position.
3. The pump in the heat exchanger will continue to circulate the water in the secondary cooling loop for 5 minutes after the laser has been de-ionized. Maintain facility power and primary cooling water during this cool down period.

It is advisable to leave the facility power on during the 5 minute cooling down period. Interrupting cooling water flow to a system that has recently been ionized may cause severe damage to tube/magnet assembly.

4. Turn off the facility circuit breaker.

5. Turn off the primary supply of facility cooling water to prevent over-pressurization of the heat exchanger primary cooling loop and temperature regulation valve.

If thermal stabilization of the light pickoff or etalon optic is desired, leave the keyswitch and main facility power on. This will provide optimum start-up performance if starting in light regulation mode or single-frequency mode. The maximum power drawn by the system when de-ionized without the heat exchanger pump active is 150 Watts. It will typically draw approximately 50 Watts.

Operator's Manual

Chapter Seven
Optics and Alignment Procedures

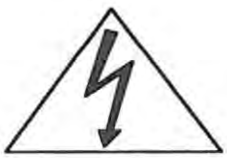
Coherent

Introduction

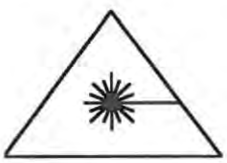
This chapter contains the following procedures:

- Inspecting and cleaning optics
- Changing cavity configurations and optics sets
- Optical alignment
- Aperture alignment

Some of the following cleaning and alignment procedures expose the operator to potential hazards of laser emission and electric shock. To minimize these hazards, follow these guidelines:



Circuits in the laser head operate at high voltages. High voltages can be lethal. Use extreme caution whenever operation without the laser head sub-covers is required.



Operating the laser without the protective housing in place exposes the operator to hazardous laser and collateral radiation. Wear safety glasses that protect against the wavelengths employed.

Care and Cleaning of Optics

The Sabre maintenance kit contains the following optics cleaning supplies: hemostats, two small medicine droppers, bottles of methanol and acetone, and lens cleaning tissue. It is recommended that an ample supply of reagent-grade methanol and Kodak lens cleaning tissues be maintained at all times. Though less commonly used, reagent-grade acetone is also acceptable but should be followed by methanol.

Laser optics should be handled with utmost care. The slightest scratch, trace of dirt or film will severely diminish the laser's efficiency. Before cleaning optics, make sure your hands are thoroughly clean and that a clean, soft, working surface is available.

Optics and optic coatings can be easily chipped or scratched. Therefore, to prevent damage when removing or replacing mirrors, always grasp the optic by the outer edge — never touch optical surfaces.

Always disengage PowerTrack during any cleaning or alignment procedure.

Optics cleaning is not required as part of regular maintenance. Optics should only be cleaned as corrective action for marked power decrease or poor mode quality.

Optics Inspection

1. Remove optic from holder and place the optic on its edge on a clean piece of lens tissue. Do not allow the optic to rest on one of its polished surfaces. Allow approximately five minutes for the optic to cool down to room temperature.

2. Once the optic has cooled, examine the optic at different light angles for signs of dirt or scratches. If scratches or dirt are present, clean the optic using the cleaning procedures located in this chapter. If the scratches are still present, a new optic will need to be ordered. Refer to Appendix A, Parts List, for the correct part number.

3. If no scratches are visible, breathe on the optic. The optic surface should fog with no discoloration. If discoloration appears, the coating has been damaged and will need replacing. Refer to Appendix A, Parts List, for the correct part number.

4. Once the optic inspection has been completed, clean both surfaces of the optic, if required, using the cleaning procedures located in this chapter and replace the optic back into the system.

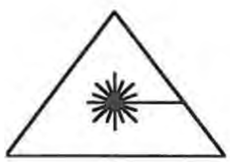
Optics Cleaning

Handle laser optics with care. A scratch, trace of dirt or film will diminish the laser's efficiency. Before cleaning optics, make sure your hands are clean and that a clean, cushioned work surface is available.

Cleaning optical surfaces too often increases the possibility of scratching mirror surfaces and therefore may shorten the useful life. Keep the laser head cover closed to prevent contamination of the cavity optics, and store optics not currently being used in sealed containers.

Optics Cleaning Methods

There are two established methods for optics cleaning: the Drop and Drag Method and the Hemostat and Lens Tissue Method. Use the Drop and Drag Method to clean optics that are easily removed from the laser head, such as the high reflector mirror, with a minimal abrasive force. The Hemostat and Lens Tissue Method is excellent for cleaning all optics, particularly hard-to-reach surfaces such as the Brewster window and the outer surface of the output coupler on a sealed mirror plasma tube.



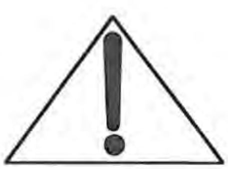
Safety glasses or goggles, which protect against the wavelengths used, should be worn at all times during these procedures.

The Drop and Drag Method

1. Place a drop of methanol in the center of a lens tissue. Hold the optic in one hand. Place the wet portion of the lens tissue on the optic surface and slowly drag it across the optic (Figure 7-1). The lens tissue and optic should be nearly dry before completing the drag.

2. Examine the surface of the optic in different lights for streaks of film. If streaks remain, repeat the process using a fresh lens tissue.

3. Re-insert the optic, being careful not to scratch the mirror surface.



On the side of each Coherent optic a small arrow (>) is printed. This arrow denotes the side that must point toward the laser cavity.

Figure 7-1. Cleaning an Optic using the Drop and Drag Method

Hemostat and Lens Tissue Method

1. Fold a lens tissue into a 1 cm (3/8 in.) wide strip, being careful not to touch the portion of the tissue that will contact the optic.

2. Fold this strip upon itself twice and grasp near the fold with clean hemostats as shown in Figure 7-2.

3. Place a few drops of methanol on the fold and shake off the excess.

4. Make a single wipe across the surface of the optic. Do not re-use the lens tissue as particles of dust and other contaminants picked up from the surface may scratch the surface if dragged across with a second wipe.

Figure 7-2. Cleaning an Optic using the Hemostat and Lens Tissue Method

Multiline High Reflector

1. Turn PowerTrack Off, operate in Current Regulation Mode, and set the automatic aperture to the OPEN position. Initiate the TUNE procedure to automatically maximize the output power. Observe power and, if possible, transverse laser mode.

2. Close intracavity shutter.

3. Unscrew the small knurled cap on the multiline rear mirror holder taking care not to release the entire assembly from its bayonet mount.

4. Pull out the small cylindrical mirror carrier.

5. Clean the exposed surface of the high reflector using the Drop and Drag Method. If the high reflector is removed from the mirror carrier, note the direction of the arrow on the side of the optic. It should face the intracavity space when re-inserted.

6. Re-insert the mirror carrier and orientate it rotationally such that the small dowel pin on the mirror carrier mates with the slot in the mirror holder. Screw on the knurled cap.

7. Open the intracavity shutter.

8. Initiate the TUNE procedure to automatically maximize the output power.

9. If power or transverse laser mode has degraded, re-clean optic.

10. If no other optics are to be cleaned, restore the desired automatic aperture position and regulation mode and setting. Turn PowerTrack On.

Single Line High Reflector and Prism

If only the prism is to be cleaned, skip steps 8 through 10. If only the high reflector is to be cleaned, skip steps 5 through 7.

1. Turn PowerTrack Off, operate in Current Regulation Mode, and set the automatic aperture to the OPEN position. Initiate the TUNE procedure to automatically maximize the output power. Observe power and, if possible, transverse laser mode.

2. Close intracavity shutter.

3. Remove the single line rear mirror holder from its bayonet mount by turning the whole assembly counterclockwise until it unlocks, then pull it out.

4. Unscrew the large knurled ring and remove the cover.

5. Turn the small plate (over the prism) to one side to allow easy access to the prism.

6. Clean each of the exposed angled surfaces with one continuous wipe beginning at the prism base using the Hemostat and Lens Tissue Method. A common error is to spray excess cleaning solvent onto the high reflector while wiping the front surface of the prism. Exercise caution if the high reflector did not initially require cleaning.

7. Re-center the small plate over the prism.

8. Remove the high reflector by lifting and moving the spring clip to the side.

9. Grasp the high reflector by its edge while removing it and clean the coated surface (indicated by the arrow on the side of the optic) using the Drop and Drag Method.

10. Re-insert the high reflector with the arrow on the side of the optic pointing toward the holder. Lift and move the spring clip back in place.

11. Re-assemble the cover and knurled ring.

12. Re-install the mirror holder into its bayonet mount turning clockwise until it locks into place

13. Open the intracavity shutter.

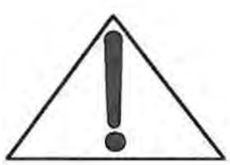
14. Initiate the TUNE procedure to automatically maximize the output power.

15. If power or transverse laser mode has degraded, re-clean optic(s).

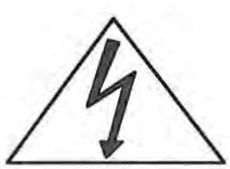
16. If no other optics are to be cleaned, restore the desired automatic aperture position and regulation mode and setting. Turn PowerTrack On.

Brewster Window

The plasma tube will have one or two Brewster windows depending on the system type. Sealed mirror systems only have a cathode window that is located near the rear of the laser head. Other system types are two-windowed and include an anode window near the front of the laser head.



Use care when cleaning the Brewster window. A scratch on the window surface may degrade performance to the extent that the tube will have to be replaced. The Brewster window is in a sealed cavity and will rarely need to be cleaned.



Turn off laser before cleaning the Brewster window. Extremely high voltage is present adjacent to the window when the laser is on. This voltage may cause serious shock to the operator or, if shorted to ground, may result in catastrophic damage to the tube and power supply.

---

1. Turn PowerTrack Off, operate in Current Regulation Mode, and set the automatic aperture to the OPEN position. Initiate the TUNE procedure to automatically maximize the output power. Observe power and, if possible, transverse laser mode.

2. Turn off the laser and keyswitch but maintain facility electrical power during the Sabre heat exchanger cool down time period.

3. Remove the appropriate laser head sub-cover.

4. On the cathode (rear) window, ease the dust shield bellows towards the rear of the head to expose the Brewster window. There will be some resistance when sliding the bellows because Teflon® O-rings produce seals to the window stem and aperture transition tube. Slight back and forth rotations of the bellows while sliding will be helpful.

   On the anode (front) window, grasp the knurled ring of the front transition tube and the dust shield bellows. Slide the two as a unit towards the front of the head until the knurled ring is fully seated in the front bayonet mount. Slight back and forth rotations of the two while sliding will be helpful in overcoming seal resistance. Push the bellows all the way onto the front transition tube to expose the Brewster window.

5. Clean the Brewster window using the Hemostat and Lens Tissue Method (Figure 7-3). Make a single wipe with a smooth continuous motion using light pressure. Do not reuse the lens tissue. Wipe in the correct direction as follows:

   On the cathode (rear) window, wipe from TOP to BOTTOM. Never wipe the cathode window from bottom to top because chips can be broken from the sharp bottom edge of the window stem and be dragged across the Brewster window surface, possibly scratching it.

   On the anode (front) window, wipe from BOTTOM to TOP, because this window is inverted. Never wipe the anode window from top to bottom.

Use a single wipe of lens tissue to avoid re-contamination or damage to the Brewster window surface. If cleaning is necessary, use a new piece of lens tissue.

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6. After cleaning a window, wait about 15 seconds to allow vapors to evaporate.

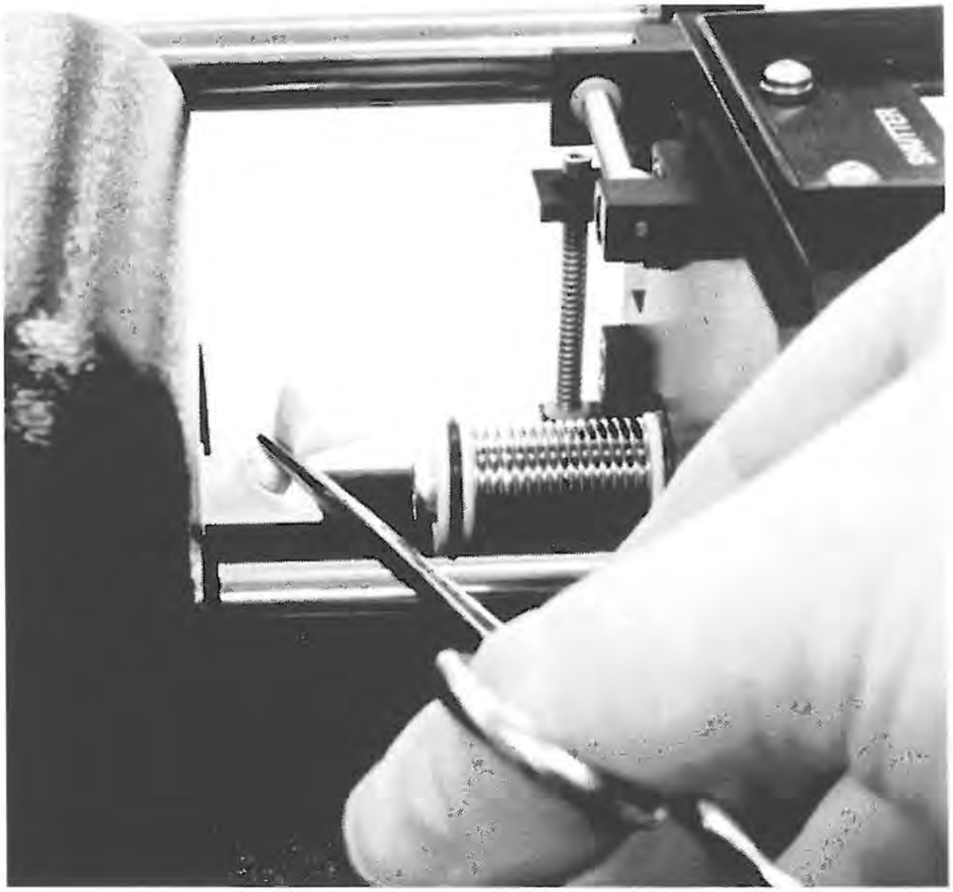


Figure 7-3. Brewster Window Cleaning

7. On the cathode (rear) window, replace the bellows using slight back and forth rotations while sliding to overcome seal resistance. Ensure that the bellows is not overextended and has good seals on both the window stem and the aperture transition tube.

   On the anode (front) window, grasp the knurled ring of the front transition tube and hold it to keep it seated in the front bayonet mount. (Failure to do so may drive the end of the transition tube into the window while replacing the bellows.) Slide the bellows towards the Brewster window with back and forth rotations until it seals on the window stem. Using the knurled ring, slide the front transition tube out of its seat in the bayonet mount approximately 1/8 of an inch (~3 mm) towards the window to allow for a kinematic seal. Ensure that the bellows is not overextended and that there are three good seals to the bayonet mount, front transition tube, and window stem.

Note: On systems with the deep or short UV options equipped with the nitrogen purge, the bellows have small venting holes drilled into the last "fold" of the bellows. Ensure that the end of the bellows with the venting holes is oriented to seal around the Brewster window stem.

8. Replace the appropriate laser head sub-cover.
9. Restart the laser.
10. Initiate the TUNE procedure to automatically maximize the output power.
11. If power or transverse laser mode has degraded, re-clean the window(s).
12. If no other optics are to be cleaned, restore the desired automatic aperture position and regulation mode and setting. Turn PowerTrack On.

Output Coupler

Depending on system type, the anode (front) end of the plasma tube will either have a sealed mirror output coupler or a Brewster window. The output coupler (OC) in a two-windowed system is contained in the front bayonet mount.

Coherent ion laser output couplers are made with a 0.5° wedge between the coated and exit faces as shown in Figure 7-4. Rotation of the output coupler, therefore, will slightly change the direction of the output beam. Less critically, rotation of the output coupler will also change the location of the secondary beam relative to the output beam.

The orientation of the wedge is indexed by a flat plane ground into side of the cylindrical optic. The flat is perpendicular to the plane determined by the wedge angle such that the flat is located at the "thin" edge of the output coupler. (Figure 7-4 illustrates an edge-on-view of the flat plane.)

In two-windowed system, the output coupler is mechanically keyed to the front bayonet mount to prevent rotation of the optic and to maintain a consistent orientation of the wedge angle. The flat of the optic mates with a machined detail in the mirror carrier. This arrangement assures that the beam exits the laser head at the same angle before and after cleaning or changing an optic. In sealed mirror systems, the wedge orientation is determined by manufacturing processes and is

invariant. In either case, the nominal wedge orientation is set so that the secondary beam is located below the main beam as it exits the laser head.

A wedge in the upper beamsplitter optic compensates for the downward slope of the beam exiting the output coupler. The resulting system output beam nominally has a slight upward slope, ~0.48 mrad, relative to the intracavity beam axis and system head level.

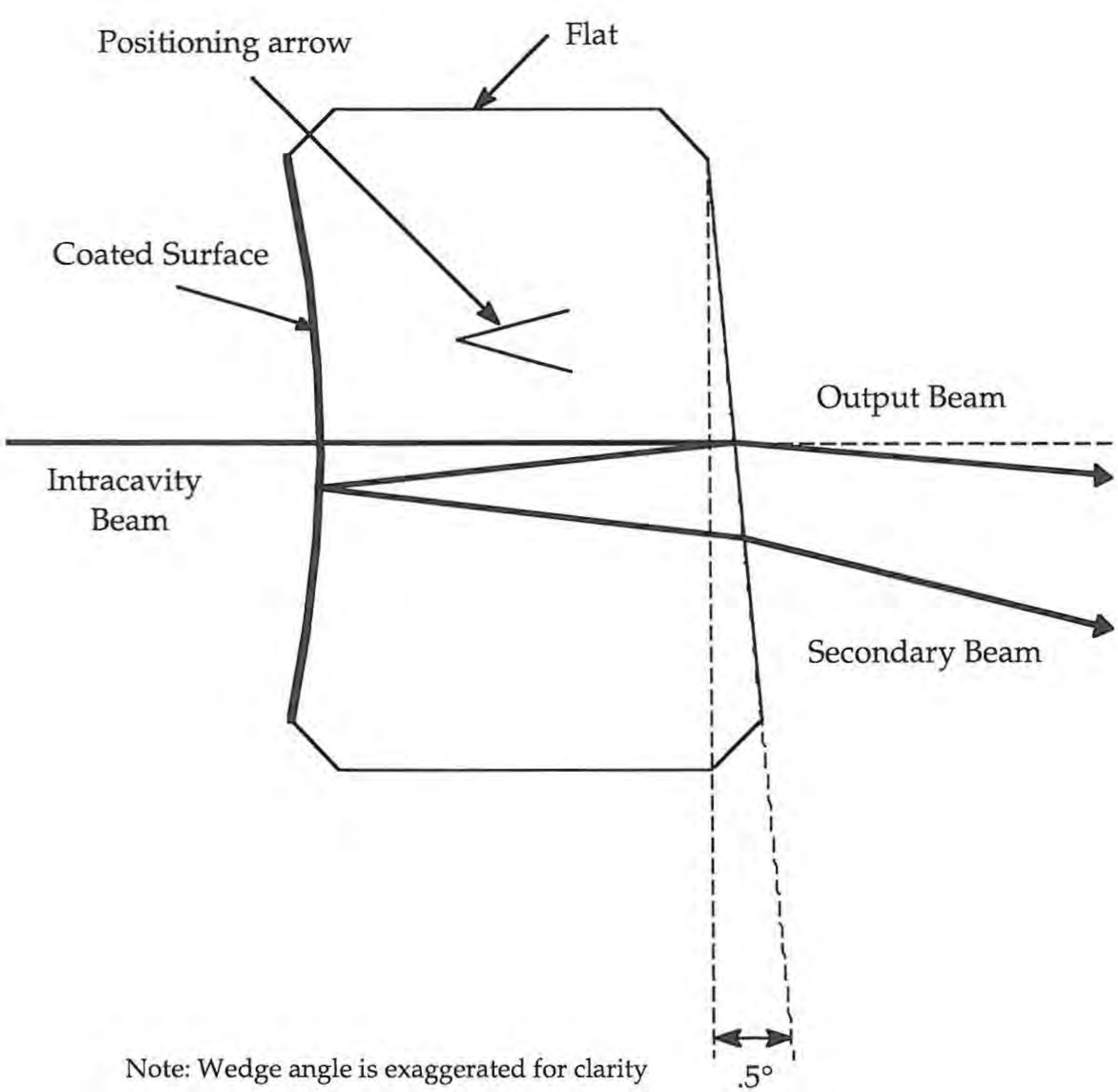
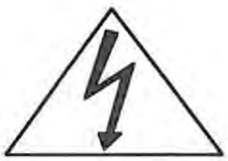


Figure 7-4. Side View of the Output Coupler Wedge Angle

Bayonet Mounted OC



Turn off laser before removing bayonet mount and cleaning output coupler. Extremely high voltage is present adjacent to the window when the laser is on. This voltage may cause serious shock to the operator or, if shorted to ground, may result in catastrophic damage to the tube and power supply.

1. Turn PowerTrack Off, operate in Current Regulation Mode, and set the automatic aperture to the OPEN position. Initiate the TUNE procedure to automatically maximize the output power. Observe power and, if possible, transverse laser mode.

2. Turn off the laser and keyswitch but maintain facility electrical power during the Sabre heat exchanger cool down time period.

3. Remove the front laser head sub-cover.

4. Grasp the knurled ring of the front transition tube and the dust shield bellows. Slide the two as a unit towards the front of the head until the knurled ring is seated in the front bayonet mount. Slight back and forth rotations of the two while sliding will be helpful in overcoming seal resistance. Push the bellows all the way onto the front transition tube. Carefully remove the front transition tube and bellows as a single unit by sliding them out of the bayonet mount with slight back and forth rotations to overcome seal resistance. While sliding out the transition tube and bellows, angle them down and to the side, away from the Brewster window to avoid contact and potential damage to the window as the seal friction is relieved.

5. Remove the front bayonet mount by turning the whole assembly counterclockwise until it unlocks. Carefully pull it out, avoiding possible contact with the Brewster window.

   Note: On systems with the deep or short UV options equipped with the nitrogen purge, it may be desirable to detach the connection where purge line mates with the front bayonet mount before unlocking the bayonet

mount. Simply pull the purge line off of the plastic nipple on the bayonet mount. Try to avoid possible contamination of the free end of the purge line and/or the nipple fitting while they are detached.

6. Unscrew and remove the knurled cap from the bayonet mount assembly.

7. Remove the mirror carrier from the bayonet mount assembly. To overcome the friction of the o-ring seal, rock the mirror carrier side to side while sliding it out of the bayonet mount.

8. Grasp the output coupler by its sides perpendicular to the flat. Remove it from the mirror carrier by rocking it side to side while sliding to overcome the friction of the dimple-to-flat interface. Note the position of the arrow on the side of the optic while removing it from the carrier. It should point away from the mirror carrier. Do not allow the O-ring to fall out of the mirror carrier.

9. Clean both sides of the output coupler using the Drop and Drag Method.

10. Re-insert the output coupler into the mirror carrier with the arrow on the side of the optic pointing away from the mirror carrier. Ensure that an O-ring is sandwiched between the optic and the mirror carrier interior. Angle the optic slightly to slip the flat under the dimple in the finger of the mirror carrier while inserting to avoid damage to the optic.

11. Insert the mirror carrier into the bayonet mount assembly orientating the carrier such that its slot indexes with the finger on the bayonet mount assembly.

12. Replace the knurled cap and tighten.

13. Re-install the front bayonet mount turning clockwise until it locks into place.

    Note: On systems with the deep or short UV options equipped with the nitrogen purge, reconnect the purge line to the plastic nipple on the front bayonet mount.

14. Re-install the front transition tube and bellows as a unit into the bayonet mount and slide them in until the knurled ring of the transition tube is fully seated in the bayonet mount. Grasp the knurled ring of the front

transition tube and hold it to keep it seated in the front bayonet mount. (Failure to do so may drive the end of the transition tube into the window while replacing the bellows.) Slide the bellows towards the Brewster window with back and forth rotations until it seals on the window stem. Using the knurled ring, slide the front transition tube out of its seat in the bayonet mount approximately 1/8 of an inch (~3 mm) towards the window to allow for a kinematic seal. Ensure that the bellows is not overextended and that there are three good seals to the bayonet mount, front transition tube, and window stem.

Note: On systems with the deep or short UV options equipped with the nitrogen purge, the bellows have small venting holes drilled into the last "fold" of the bellows. Ensure that the end of the bellows with the venting holes is oriented to seal around the Brewster window stem.

15. Insert two 1/8 inch Allen wrenches through the access holes in the front bezel to mate with the Vertical and Horizontal Output Coupler Mirror Plate Adjusts. (Refer to Figure 5-10 for the location of the adjustment screws.)

16. Replace the laser head front sub-cover.

17. Restart the laser.

18. If the system is lasing, peak up the power using only the Vertical and Horizontal Output Coupler Mirror Plate Adjusts. If the system is not lasing, refer to the subsequent section and related sub-sections: MIRROR ALIGNMENT PROCEDURES: Output Coupler.

19. Initiate the TUNE procedure to automatically maximize the output power.

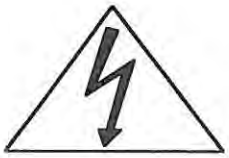
20. If power or transverse laser mode has degraded, re-clean the output coupler.

21. If no other optics are to be cleaned, restore the desired automatic aperture position and regulation mode and setting. Turn PowerTrack On.

Sealed Mirror OC

The exit face of the output coupler in a sealed mirror system will typically not need cleaning as it is sealed off fairly well from external contamination. Cleaning will only be required

when operating in extremely dirty conditions. The intracavity surface is completely inaccessible.



Turn off laser before cleaning the exit surface of the sealed mirror output coupler. Extremely high voltage is present adjacent to the output coupler when the laser is on. This voltage may cause serious shock to the operator or, if shorted to ground, may result in catastrophic damage to the tube and power supply.

---

1. Turn PowerTrack Off, operate in Current Regulation Mode, and set the automatic aperture to the OPEN position. Initiate the TUNE procedure to automatically maximize the output power. Observe power and, if possible, transverse laser mode.

2. Turn off the laser and keyswitch but maintain facility electrical power during the heat exchanger cool down time period.

3. Remove the front laser head sub-cover.

4. Remove the front bezel by loosening the two mounting screws accessible from the front of the bezel and located on the lower corners. Swing the bezel to the side maintaining the electrical connections.

5. Remove the strain relief clamp holding the cables to the external shutter mounting bracket. Note the spacing of the external shutter relative to the front mirror plate assembly and beamsplitter mounting block. Remove the lower two screws fastening the external shutter mounting bracket to the laser head baseplate. Swing the external shutter aside allowing access to the beamsplitter mounting block.

6. Remove the three beamsplitter mounting block fastener screws, shown on Figure 7-5 and remove the block from the front mirror plate.

7. Clean the exit face of the output coupler using the Hemostat and Lens Tissue Method. Modify this method slightly, cleaning the optic from the center to the outer edges. This technique will prevent possible damage to the optic due to the dragging of particulates from the

outer edge and surrounding insulating material over the optic surface, scratching it.

8. Replace and realign the beamsplitter mounting block using the appropriate procedures described in the subsequent section titled: BEAMSPLITTER MOUNTING BLOCK ALIGNMENT.

9. Realign the TEM_{00} detector assembly using the appropriate procedures described in the subsequent section titled: TEM_{00} DETECTOR ASSEMBLY ALIGNMENT.

10. Re-mount the external shutter and cable strain relief clamp. Realign the external shutter using the appropriate procedures described in the subsequent section titled: EXTERNAL SHUTTER ALIGNMENT.

11. Replace bezel and sub-cover. Restart the laser.

12. If power or transverse laser mode has degraded, re-clean optic.

13. If no other optics are to be cleaned, restore the desired automatic aperture position and regulation mode and setting. Turn PowerTrack On.

Output Window

The output window is incorporated into the exit aperture of the front bezel (refer to Figure 5-10). The window, oriented at Brewsters angle, minimizes interactions between the beam internal to the laser head and external environmental conditions. The output window assembly will typically only need cleaning when operating in extremely dirty conditions.

Use the following procedure to clean the output window.

1. Close the external shutter if the system is ionized by pressing the SHUTTER button on the remote such that the LED above the button is off.

2. Unscrew and remove the output nut on the exterior of the front bezel.

3. Slide the output window assembly out of the front bezel aperture.

4. Clean the two polished surfaces of the output window optic using the Hemostat and Lens Tissue Method. On

the surface facing away from the assembly body, the method may be modified slightly by wiping from the center of the optic towards the edges to avoid dragging particulates from the rough edges of the optic onto the polished surface. On the surface facing inward towards the assembly body, attempt to place the lens tissue completely on the polished surface of the optic without contacting the assembly body before initiating the wipe. The free "tails" of the folded tissue may be folded to the side and back or cut off to facilitate insertion of the cleaning surface of the lens tissue into the assembly body.

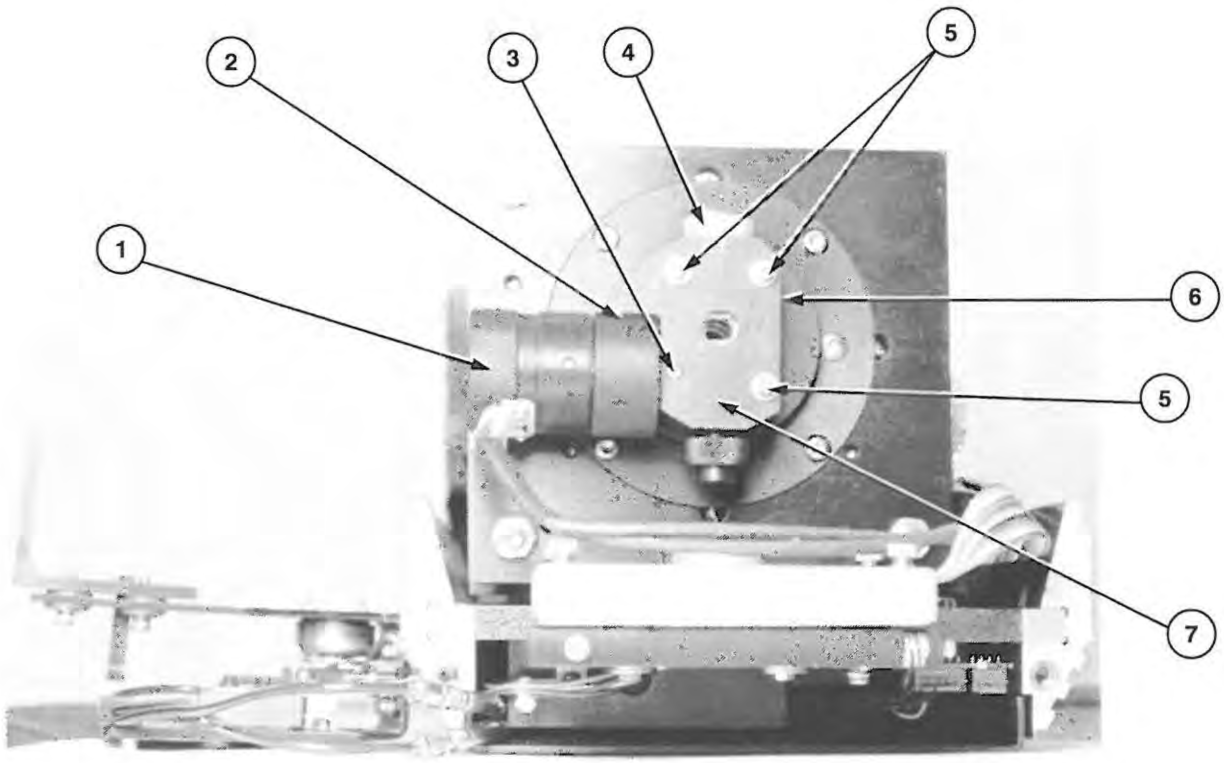
5. Reinsert the output window assembly into the front bezel aperture. Ensure that the assembly is pushed all the way in and rotated correctly to mate the dowel pin on the output window assembly with the slot in the front bezel aperture.

6. Replace the output nut on the exterior of the front bezel.

Beamsplitters

The beamsplitter assembly is located inside of its mounting block on the front mirror plate as shown on Figure 7-5. The beamsplitter assembly is captured in its mounting block by a set screw on the side of the block. The assembly is rotationally indexed in the block by a small dowel pin on the assembly and a slot in the block. This facilitates restoration of alignment and maintains photocell light power calibration if the beamsplitter assembly is removed from its block for inspection of cleanliness.

There are two unique optics in the beamsplitter assembly, as shown in Figure 7-6. The upper optic, which samples the output beam directly, has a chamfered corner to distinguish it from the lower beamsplitter optic. The lower beamsplitter reflects a portion of the beam to the side onto the photocell and transmits the rest straight down to the TEM_{00} detector.



1. Photocell assembly
2. Photocell knurled cap
3. Photocell set screw
4. Beamsplitter assembly
5. Mounting block fastener screws
6. Beamsplitter assembly set screw (on side)
7. Beamsplitter mounting block

Figure 7-5. Beamsplitter Assembly and Mounting Block

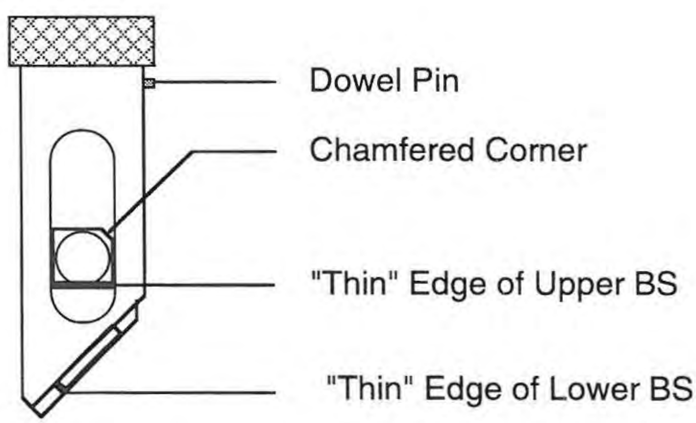


Figure 7-6. Beamsplitter Assembly

Each optic has nonparallel entrance and exit surfaces with a unique wedge angle between the surfaces. The different wedges of the optics and the orientations of each in the beamsplitter assembly, as shown in Figure 7-6, ensure that multiple reflections from each optic converge at the photocell and the TEM_{00} detector.

Beamsplitter Cleaning

The beamsplitter assembly in its mounting block will typically not need cleaning as it is sealed off fairly well from external contamination. Cleaning will only be required when operating in extremely dirty conditions.

Use the following procedure to clean either of the beamsplitter optics.

1. Shut down the system and remove the front sub-cover.
2. Loosen the beamsplitter assembly set screw, shown in Figure 7-5, and remove the assembly from the mounting block.
3. Clean the two polished surfaces of each beamsplitter optic using the Hemostat and Lens Tissue Method, as shown in Figure 7-7. On the surfaces facing away from the assembly body, the method may be modified slightly by wiping from the center of the optics towards the edges to avoid dragging particulates from the rough edges of the optics onto the polished surfaces. On the surfaces facing inward towards the assembly body, attempt to place the lens tissue completely on the polished surface of the optic without contacting the rough edges before initiating the wipe. The free "tails" of the folded tissue may be folded to the side and back or cut off to facilitate insertion of the cleaning surface of the lens tissue into the beamsplitter body.
4. Return the beamsplitter assembly to its mounting block. Ensure that the assembly is pushed all the way down and rotated correctly to mate the dowel pin on the beamsplitter assembly with the slot on the mounting block.
5. Tighten the beamsplitter assembly set screw.
6. Although it should not be necessary, it may be desired to check the alignment of the reflected beams going to the photocell and the transmitted beams going to the TEM_{00} detector using the next two procedures described below.

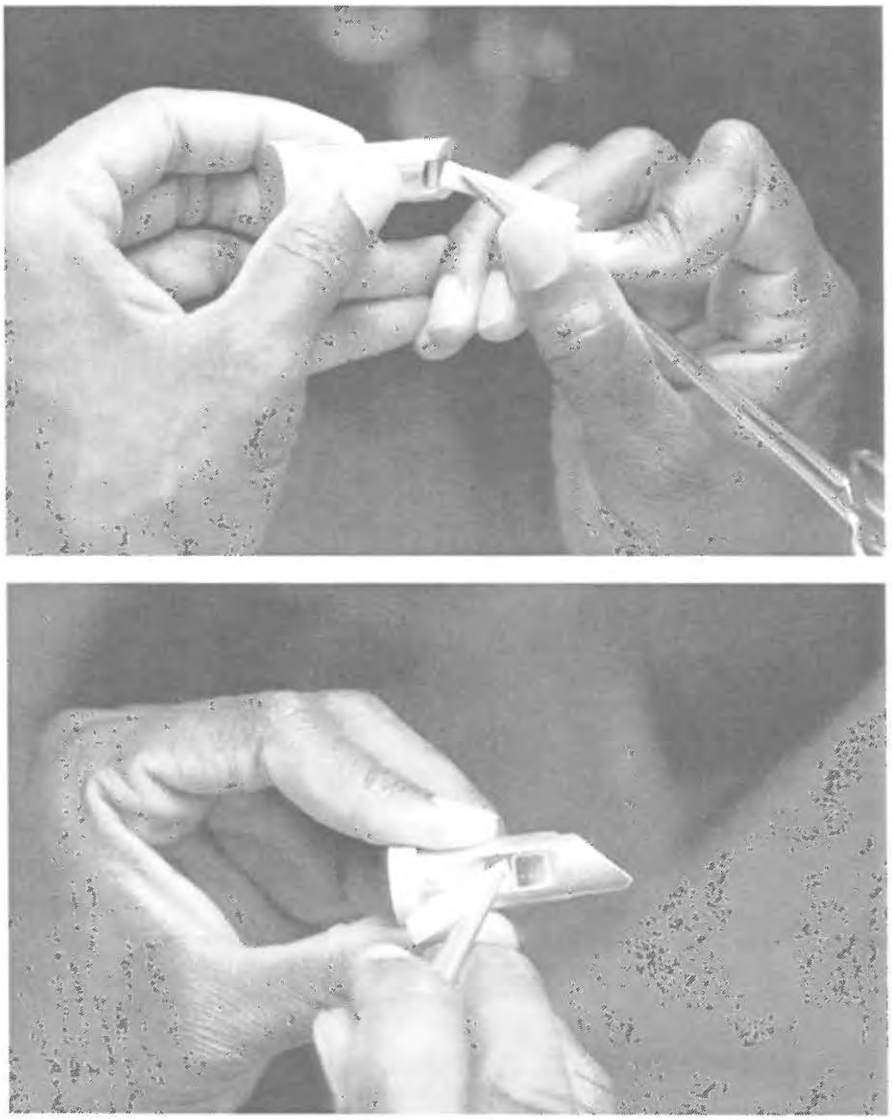
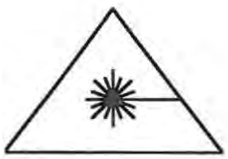


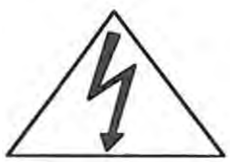
Figure 7-7. Beamsplitter Cleaning

Beamsplitter Mounting Block Alignment

When the beamsplitter mounting block is removed for cleaning of the exit surface of a sealed mirror output coupler, it may be necessary to realign it to ensure centered incidence of the reflected beams on the photocell. Correct execution of the procedure should maintain accurate light power calibration.



Operating the laser without the protective housing in place exposes the operator to hazardous laser and collateral radiation. Wear safety glasses that protect against the wavelengths employed.



Circuits in the laser head operate at high voltages. HIGH VOLTAGES CAN BE LETHAL. Use EXTREME CAUTION whenever operation without the laser head sub-covers is required.

To check the alignment of the beamsplitter mounting block or to realign it, perform the following procedure:

1. Turn PowerTrack Off, operate in Current Regulation Mode, and set the automatic aperture to the OPEN position. It is advantageous to operate at a low output power level when performing this procedure. Initiate the TUNE procedure to automatically maximize the output power.

2. Turn off the laser and keyswitch but maintain facility electrical power during the heat exchanger cool down time period.

3. Remove the front laser head sub-cover.

4. Remove the front bezel by loosening the two mounting screws accessible from the front of the bezel and located on the lower corners. Swing the bezel to the side maintaining the electrical connections. Install the interlock defeat to the bezel.

5. Remove the strain relief clamp holding the cables to the external shutter mounting bracket. Note the spacing of the external shutter relative to the front mirror plate assembly and beamsplitter mounting block. Remove the lower two screws fastening the external shutter

mounting bracket to the laser head baseplate. Swing the external shutter aside allowing access to the beamsplitter mounting block.

6. Loosen the photocell set screw, shown in Figure 7-5 and remove the photocell assembly.

7. Carefully unscrew and remove the photocell knurled cap, shown in Figure 7-5. Maintain a vertical orientation of the photocell assembly to prevent the photocell optics from falling out of the assembly.

8. Re-mount the photocell knurled cap only into the beamsplitter mounting block and tighten the retaining set screw.

9. Ensure that the output beam path is unobstructed and put an appropriate beam block in the photocell beam path.

10. Restart the laser.

11. Observe the four spots reflected from the beamsplitters in the photocell beam path. The four spots should converge approximately 2 to 2.5 inches (5 to 6.4 cm) relative to the resonator's optic axis.

12. Using a lens tissue or white card, check for a centered alignment of the converging spots in the aperture of the photocell knurled knob. If alignment is acceptable, skip the next two steps and continue with step 15.

13. Slightly loosen the three beamsplitter mounting block fastener screws, shown in Figure 7-5.

14. Maintaining an overall vertical orientation of the beamsplitter mounting block, translate the block vertically and/or horizontally to center the reflected spots in the aperture of the photocell knurled knob. When centered, tighten the three fastener screws.

15. Shut down the laser.

16. Remove the photocell knurled knob from the beamsplitter mounting block and screw it onto the photocell assembly. Re-install the photocell assembly into the beamsplitter mounting block and secure the set screw.

17. Realign the TEM_{00} detector assembly using the appropriate procedures described in the subsequent section titled: TEM_{00} DETECTOR ASSEMBLY ALIGNMENT.

18. Re-mount the external shutter and cable strain relief clamp. Realign the external shutter using the appropriate procedures described in the subsequent section titled: EXTERNAL SHUTTER ALIGNMENT.

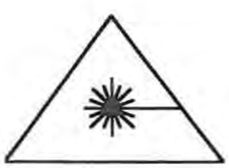
19. Replace bezel, remove the interlock defeat, and replace the laser head sub-cover.

20. Restart the laser.

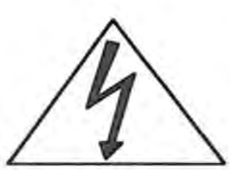
21. Restore the desired automatic aperture position and regulation mode and setting. Turn PowerTrack On.

TEM_{00} Detector Assembly Alignment

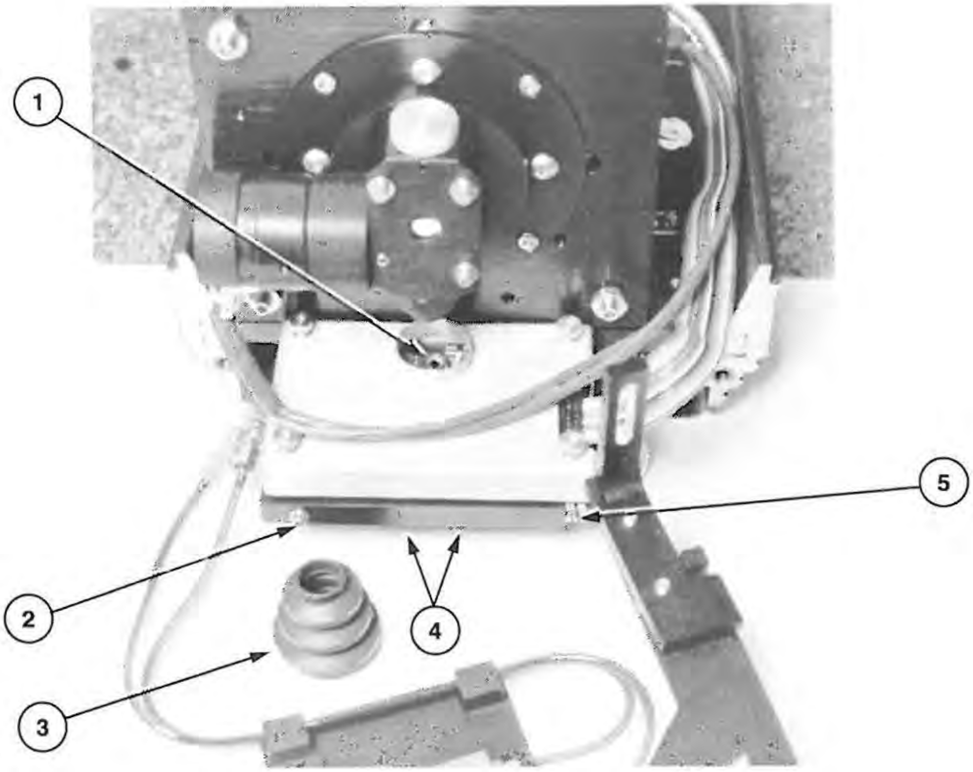
The TEM_{00} detector assembly contains an adjustable stage that allows for fine horizontal and vertical translation of the detector's photocell relative to the TEM_{00} detector reflected beam path (refer to Figure 7-8). Coarse translation of the assembly is accommodated by clearance in the assembly's mounting holes relative to the mounting screws.



Operating the laser without the protective housing in place exposes the operator to hazardous laser and collateral radiation. Wear safety glasses that protect against the wavelengths employed.



Circuits in the laser head operate at high voltages. HIGH VOLTAGES CAN BE LETHAL. Use EXTREME CAUTION whenever operation without the laser head sub-covers is required.



1. TEM_{00} detector photocell
2. Fine vertical adjust
3. Viton bellows
4. Assembly mounting screws (not visible in picture, under baseplate)
5. Fine horizontal adjust

Figure 7-8. TEM_{00} Detector Assembly

To check the alignment of the TEM_{00} detector assembly or to realign it, perform the following procedure:

1. Turn PowerTrack Off, operate in Current Regulation Mode, and set the automatic aperture to the OPEN position. It is advantageous to operate at a low output power level when performing this procedure. Initiate the TUNE procedure to automatically maximize the output power.

2. Turn off the laser and keyswitch but maintain facility electrical power during the heat exchanger cool down time period.

3. Remove the front laser head sub-cover.

4. Remove the front bezel by loosening the two mounting screws accessible from the front of the bezel and located

on the lower corners. Swing the bezel to the side maintaining the electrical connections. Install the interlock defeat to the bezel.

5. Remove the Viton bellows beam seal between the beamsplitter mounting block and the TEM_{00} detector assembly.

6. Restart the laser.

7. Observe the reflected converging spots on the detector's photocell. If the spots appear to be getting "clipped", check the alignment of the beamsplitter mounting block as described in the preceeding section. If the photocell requires cleaning, shut down the system, turn off the keyswitch, and wipe clean using the Hemostat and Lens Tissue Method.

8. Using a 3/32 inch Allen wrench in the Fine Vertical or Horizontal Adjust, translate the stage to center the reflected converging spots on the detector's photocell.

9. If the one or both of the ranges of the Fine Adjusts is insufficient, watch the translation of the stage while rotating each though its full range to determine the midrange of each Fine Adjust. Set each Fine Adjust to its midrange position. Using a 1/4 inch box wrench, slightly loosen the TEM_{00} detector assembly mounting screws located under the laser head baseplate. Coarsely adjust the assembly to center the converging spots on the detector's photocell and tighten the mounting screws. Complete alignment using the Fine Adjusts.

10. Shut down the laser.

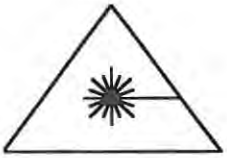
11. Replace the Viton bellows and rotate or fully examine to ensure proper seals.

12. Replace bezel, remove the interlock defeat, and replace the laser head sub-cover.

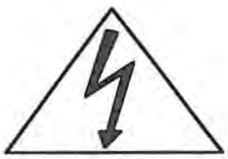
13. Restart the laser.

14. Restore the desired automatic aperture position and regulation mode and setting. Turn PowerTrack On.

External Shutter Alignment



Operating the laser without the protective housing in place exposes the operator to hazardous laser and collateral radiation. Wear safety glasses that protect against the wavelengths employed.



Circuits in the laser head operate at high voltages. HIGH VOLTAGES CAN BE LETHAL. Use EXTREME CAUTION whenever operation without the laser head sub-covers is required.

To check the alignment of the external shutter or to realign it, perform the following procedure:

1. Turn PowerTrack Off, operate in Current Regulation Mode, and set the automatic aperture to the OPEN position. It is advantageous to operate at a low output power level when performing this procedure. Initiate the TUNE procedure to automatically maximize the output power.
2. Turn off the laser and keyswitch but maintain facility electrical power during the heat exchanger cool down time period.
3. Remove the front laser head sub-cover.
4. Remove the front bezel by loosening the two mounting screws accessible from the front of the bezel and located on the lower corners. Swing the bezel to the side maintaining the electrical connections. Install the interlock defeat to the bezel.
5. Restart the laser.
6. Close the external shutter using the remote.
7. Observe the location of the output beam on the water cooled beam dump block of the external shutter. The output beam and the secondary beam should both be contained within the square aperture of the block. The output beam should be fairly well centered in the

aperture and hit the beveled edge within the beam dump assembly. Ensure that no beams exit the laser head. Provide for clearance between the external shutter assembly and the beamsplitter mounting block.

8. Open the external shutter using the remote. Ensure that the beam dump block does interfere with the output beam in any way.

9. Adjustments in the transverse plane relative to the resonator's optic axis may be made by loosening the two screws clamping the blue dampening material on the vertical portion of the external shutter mounting bracket and orientating as needed. Re-tighten the two screws but do not over-tighten.

   Adjustments parallel to the resonator's optic axis may be made by loosening the two lower screws fastening the external shutter mounting bracket to the laser head baseplate and translating.

10. Close the external shutter using the remote and replace the front bezel. The external shutter assembly should not be in contact with any other assembly or cable. Check the clearance of the external shutter assembly in the following four areas: between the external shutter assembly and the beamsplitter mounting block, between the upper corner of the external shutter bracket and the bezel, between the interlock body in the bezel and the upper portion of the shutter bracket, and between the shutter assembly and the interior face of the bezel. Adjust accordingly.

11. Shut down laser.

12. Remove the interlock defeat and replace the laser head front sub-cover. Check clearance.

13. Restart the laser.

14. Restore the desired automatic aperture position and regulation mode and setting. Turn PowerTrack On.

Multiline/Single Line Swap

The following section provides supplementary procedures concerning changing the cavity configuration between multiline and single line within a given optic set. Besides single line wavelength changes, multiline/single line swaps

within a given optic set are among the easiest wavelength changes to implement. This is due to the fact that the output coupler need not be replaced and the automatic search procedures utilized by the motorized rear mirror plate facilitate the change.

Information concerning the details of the wavelength change routine and determination of the status of the motorized rear plate may be found in Chapter Five, System Description and Control in the section titled: LASER HEAD AND AUTOMATED FEATURES: Motorized Rear Mirror Plate: Changing Single Line Wavelengths. Information concerning optic sets and general wavelength changes may be found in Chapter Five, System Description and Control in the section titled: LASER HEAD AND AUTOMATED FEATURES: Motorized Rear Mirror Plate: General Wavelength Changes. More information concerning changing optic sets will be presented in the next section.

The following procedure should be used to perform a multiline/single line swap within a given optic set.

1. Turn PowerTrack Off, operate in Current Regulation Mode, and set the automatic aperture to the OPEN position. It is advantageous to operate at a maximum tube current when performing this procedure. Initiate the TUNE procedure to automatically maximize the output power.

2. Close the intracavity shutter.

3. Remove the original rear mirror holder from its bayonet mount by turning the whole assembly counterclockwise until it unlocks, then pull it out.

4. If the high reflector for this optic set is not in the desired rear mirror holder, install the appropriate optic or transfer it from the original rear mirror holder. Inspect the optic for cleanliness. Note, if appropriate, use the single line holder that is correct for the currently installed optic set. For argon systems, the label "VIS", "UV", or "D/SUV" is stamped on the intracavity side of the single line holder. For krypton systems, the label "VIS/IR" or "UV" is stamped on the intracavity side of the single line holder.

5. Install the desired mirror holder into the rear bayonet mount turning clockwise until it locks into place

6. Open the intracavity shutter.

7. Select the desired wavelength using the "Wavelength Menu" from the remote or use external computer control (Command: Wavelength = n). If the specified wavelength is not found, refer to Chapter Nine, Troubleshooting.

8. Select the desired automatic aperture position and regulation mode and setting. Turn PowerTrack On.

Changing Optic Sets

An optic set is defined as an output coupler (OC) and high reflector (HR) that share a common bandwidth of possible lasing wavelengths. The optic set may be installed into the system in the multiline or single line cavity configuration. The appropriate optics, single line holders, available wavelength ranges and external computer control optic set numbers previously presented in Chapter Five are repeated here for convenience as Tables 7-1 and 7-2.

Changing optic sets always requires changing of the output coupler as can be seen in Tables 7-1 and 7-2. The multiline cavity configuration for any given optic set produces the highest power and has the broadest tolerance to cavity misalignments which facilitate the success of the motorized rear mirror plate search procedures. It is, therefore, recommended to perform optic set changes in the multiline cavity configuration. Operation in the multiline configuration should be used as an intermediary step to change optic sets when the initial and final cavity configuration is single line. For example, if the desired change in operation is a single line visible to single line UV conversion, the procedure would require the following: a single line visible to multiline visible swap (as described in the preceding section), a multiline visible to multiline UV optic set change (described here), and then a multiline UV to single line UV swap. With experience, however, the procedure may be modified to skip the multiline cavity configuration conversion.

To change optic sets, assuming initial lasing operation in the multiline cavity configuration, perform the following procedures. Select the appropriate parts of the procedure that are applicable to the system type: sealed mirror or two-windowed.

Table 7-1 Argon Wavelength Selection and Optic Sets

Optic Set	Optic Set Bandwidth	Multiline Wavelength	Single Line Holder	HR	OC	Radius of OC
1	275.4 nm only [2]	275.4 nm	—	0160-493-00	0166-852-00	12 m
2	275.4 - 305.5 nm	MLDUV	D/SUV prism	0160-495-00	0166-853-00	12 m
3	300.3 - 335.8 nm	MLSUV	D/SUV prism	0161-015-00	0166-854-00	12 m
4	333.6 - 363.8 nm	MLUV	UV prism	0903-016-00	0166-855-00	12 m
5	351.1 - 385.8 nm	MLLUV	UV prism	0161-255-00	0166-856-00	12 m
6	454.5 nm only [3]	—	VIS prism	0903-004-00	0166-859-00	15 m
7	454.5 - 514.5 nm	MLVIS	VIS prism	0903-004-00	0166-858-00 or 0166-857-00 [4]	15 m
8	528.7 nm only [3]	—	VIS prism	0903-004-00	0166-860-00	10 m

[1] Single line selection is standard or available as an option dependent on optic set and system type.

[2] Requires Multiline Holder.

[3] Requires VIS Single Line Holder.

[4] Install 0166-857-00 to attain specified single line output powers of the 457.9 nm and/or Blue/Green options. Install 0166-858-00 for multiline configuration.

Table 7-2. Krypton Wavelength Selection and Optic Sets

Optic Set	Optic Set Bandwidth	Multiline Wavelength	Single Line Holder	HR	OC	Radius of OC
1	337.5 - 356.4 nm [2]	MLUV	UV prism	0903-016-00	0903-061-00	15 m
2	406.7 - 415.4 nm [2]	MLVI	VIS/IR prism	0903-062-00	0160-013-00	10 m
3	468.0 - 530.9 nm [2]	MLBG	VIS/IR prism	0903-004-00	0155-264-00 or 0161-441-00 [3]	15 m
4	520.8 - 568.2 nm	MLYG	VIS/IR prism	0903-066-00 [4]	0903-067-00 [4]	15 m
5	647.1 - 676.4 nm	MLRED	VIS/IR prism	0903-068-00	0903-070-00	10 m
6	752.5 - 799.3 nm	MLIR	VIS/IR prism	0903-064-00	0903-065-00	10 m[5]

[1] Single line selection is standard or available as an option dependent on optic set and system type.

[2] Wavelengths ≤ 468.0 nm require magnet to be set to high field.

[3] Install 0161-441-00 to attain specified single line output powers of the 468.0, 476.2, and/or 482.5 nm options. Install 0155-264-00 for multiline configuration.

[4] Install Optic Set 4 to attain specified single line output powers of the 520.8, 530.9, and/or 568.2 nm options.

[5] Radius of HR also is 10 m.

1. Turn PowerTrack Off, operate in Current Regulation Mode, and set the automatic aperture to the OPEN position. It is advantageous to operate at a maximum tube current when performing this procedure. Initiate the TUNE procedure to automatically maximize the output power.

2. If the system is sealed mirror, skip the next two steps and continue with step 5.

3. Turn off the laser and keyswitch but maintain facility electrical power during the Sabre heat exchanger cool down time period.

4. Remove the initial output coupler and install the desired (clean) output coupler using the appropriate procedures, up to and including restarting of the laser, described in the previous section titled: CARE AND CLEANING OF OPTICS: Output Coupler: Bayonet Mounted OC.

   Note: For krypton systems, the proper magnetic field must be set before restarting the laser. High field should be used for UV and violet wavelengths (≤ 468.0 nm) only.

5. Close the intracavity shutter.

6. Unscrew the small knurled cap on the multiline rear mirror holder taking care not to release the entire assembly from its bayonet mount.

7. Pull out the small cylindrical mirror carrier.

8. Remove the initial high reflector and note the direction of the arrow on the side of the optic. Install the desired (clean) high reflector into the mirror carrier with the arrow on the optic oriented to face the intracavity space when re-inserted.

9. Re-insert the mirror carrier and orientate it rotationally such that the small dowel pin on the mirror carrier mates with the slot in the mirror holder. Screw on the knurled cap.

10. Open the intracavity shutter.

11. If the system is lasing and is two-windowed, peak up the power using only the Vertical and Horizontal Output Coupler Mirror Plate Adjusts. If the system is sealed

mirror, proceed with the next step whether or not it is lasing.

12. Select the appropriate multiline wavelength using the "Wavelength Menu" from the remote. Alternatively, use external computer control to specify the optic set (Command: Optic Set = n), then wavelength (Command: Wavelength = n). If the system is not lasing and is two-windowed or sealed mirror visible, refer to the subsequent section and related sub-sections: MIRROR ALIGNMENT PROCEDURES: Output Coupler. If the specified wavelength is not found, refer to Chapter Nine, Troubleshooting.

13. Perform the appropriate procedures described in the subsequent section: MIRROR ALIGNMENT PROCEDURES: Walk-In Procedure, to align the output coupler and high reflector with respect to the bore of the plasma tube for maximum available output power and best possible transverse laser mode.

14. Check and/or correct the alignment of the automatic aperture using the appropriate procedures described in the subsequent section and related sub-sections: APERTURE ALIGNMENT PROCEDURE.

15. Convert the system to the single line configuration, if desired, using the appropriate procedures described in the previous section: MULTILINE/SINGLE LINE SWAP.

16. Select the desired automatic aperture position and regulation mode and setting. Turn PowerTrack On.

Mirror Alignment Procedures

Routines executed by the motorized rear mirror plate, to search for and optimize the output power, free the user from most manual mechanical adjustments. The search routines operate under the assumption that output coupler is sufficiently aligned such that lasing may be established through movement of the rear mirror plate only. If the alignment of the output coupler has been changed or is not known, then manual alignment of the output coupler by the user will be required.

There are three alignment procedures presented below. The first two are applicable to the output coupler only and the third optimizes alignment of both mirrors.

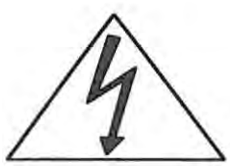
1. The Vertical Search Procedure is used to establish lasing using the output coupler.
2. Retroflection is used to coarsely align the output coupler.
3. The Walk-In Procedure optimizes the alignment of both the output coupler and high reflector with respect to the bore of the plasma tube for maximum available output power and best possible transverse laser mode.

Output Coupler

The following procedures are used set the angular alignment of the output coupler to establish lasing directly or to facilitate the search routines of the motorized rear mirror plate.

Vertical Search Procedure

Use the Vertical Search Procedure whenever the output coupler is misaligned to such an extent that the system does not to lase. Assuming that the high reflector is aligned, this procedure will rapidly and systematically scan the output coupler through a grid of possible angular positions until the mirrors are aligned and lasing is established.



Circuits in the laser head operate at high voltages. HIGH VOLTAGES CAN BE LETHAL. Use EXTREME CAUTION whenever operation without the laser head sub-covers is required.

Select the appropriate parts of the procedure that are applicable to the system type: sealed mirror or two-widowed.

1. Turn PowerTrack Off, operate in Current Regulation Mode, and set the automatic aperture to the OPEN position. It is advantageous to operate at a maximum tube current when performing this procedure.

2. Turn off the laser and keyswitch but maintain facility electrical power during the Sabre heat exchanger cool down time period.

3. Remove the front laser head sub-cover.

4. Install the interlock defeat on the front bezel.

5. Restart the laser. Note: If laser has not been shut down and restarted, then the PowerTrack actuators may not be at their centered positions. Do not use the TUNE procedure to accomplish this because it will change the known position of the rear mirror plate.

6. Open the external shutter using the remote.

7. Ensure that the intracavity shutter is open.

8. Place a white or fluorescent coated card in the path of the plasma glow that exits the output coupler to aid in detection of the initiation of lasing.

9. Using a 1/8 inch Allen wrench, turn the Vertical Output Coupler Mirror Plate Adjust 2 to 3 rotations counterclockwise to provide adequate range for rocking of the front mirror plate. (Refer to Figure 5-10 for the location of the adjustment screw.)

10. Grasping the front mirror plate near the Vertical Output Coupler Mirror Plate Adjust, pull the front mirror plate towards the front of the head and then carefully let it return to its original position. This is known as rocking the front mirror plate. Observe the card at the output of the head for a lasing FLASH. In this procedure, a FLASH is any momentary display of laser energy. If no FLASH is observed, rotate the Horizontal Output Coupler Mirror Plate Adjust very slowly in one direction while rapidly rocking the front mirror plate. (Refer to Figure 5-10 for the location of the adjustment screw.) Watch carefully for a FLASH.

    If you do not observe a FLASH after rotating the Horizontal Output Coupler Mirror Plate Adjust three full turns in one direction, reverse the turning direction of the Horizontal Adjust and repeat the scanning process until a FLASH is observed. Patience, especially in UV, is required because it is not unusual to scan horizontally back and forth several times before FLASH is observed. If this procedure is unsuccessful and the alignment of the high reflector is in question, it may be necessary to align the output coupler for retroreflection, as described in the next procedure(s), and initiate a search using the motorized rear mirror plate.

11. When a FLASH is observed, rotate the Vertical Output Coupler Mirror Plate Adjust clockwise while continuing to rock until lasing is continuous.

12. Peak up the output power using only the Vertical and/or Horizontal Output Coupler Mirror Plate Adjusts.

13. Initiate the TUNE procedure to automatically maximize the output power using the automatic rear mirror plate. Alternatively, if it is necessary, select the appropriate wavelength using the "Wavelength Menu" from the remote or use external computer control to specify the wavelength (Command: Wavelength = n).

14. Select the desired automatic aperture position and regulation mode and setting. Turn PowerTrack On.

Retroreflection

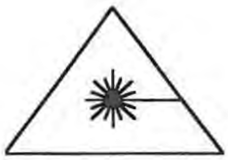
Retroreflection of the output coupler is used to establish a default starting point for the Vertical Search Procedure if necessary or to coarsely align the output coupler to facilitate success of the search routines of the motorized rear mirror plate. The basis of the procedure is to align the output coupler such that the intracavity light incident on optic is retroreflected, or re-directed upon itself, so that the reflected light propagates through the bore of the plasma tube and reaches the high reflector.

Retroreflection from the output coupler can be observed in two ways and will be presented here as two separate procedures. The retroreflection may be observed at the anode (front) Brewster window or, preferably, out of the rear of the system when the high reflector is removed. The correct procedure to use is dependent on the system type and the optic set installed.

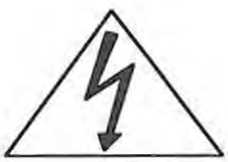
Retroreflection at the anode window is, of course, only used on two-windowed systems. It is the only procedure available for alignment of a UV output coupler and should be used when physical constraints do not allow observation at the rear of a visible system. Retroflection at the anode window is also useful as a preliminary alignment for retroreflection out of the rear of a visible system.

Retroreflection out of the rear of the system usually provides the best results and can only be used with visible sealed mirror or two-windowed systems. It may also be used as an intermediary step in UV two-windowed systems. A visible output coupler may be temporarily installed and the

procedure executed to ensure proper alignment of the output coupler and bayonet mount.



Operating the laser without the protective housing in place exposes the operator to hazardous laser and collateral radiation. Wear safety glasses that protect against the wavelengths employed.



Circuits in the laser head operate at high voltages. HIGH VOLTAGES CAN BE LETHAL. Use EXTREME CAUTION whenever operation without the laser head sub-covers is required.

RETROREFLECTION AT ANODE WINDOW:

The following procedure should be used to observe the retroreflection at the anode (front) Brewster window.

1. Turn PowerTrack Off, operate in Current Regulation Mode, and set the automatic aperture to the OPEN position. It is advantageous to operate at a maximum tube current when performing this procedure.

2. Turn off the laser and keyswitch but maintain facility electrical power during the heat exchanger cool down time period.

3. Remove the front laser head sub-cover.

4. Install the interlock defeat on the front bezel.

5. Remove the front transition tube and dust shield bellows using the appropriate procedures described in the previous section titled: CARE AND CLEANING OF OPTICS: Output Coupler: Bayonet Mounted OC.

6. Restart the laser. Note: If laser has not been shut down and restarted, then the PowerTrack actuators may not be at their centered positions. Do not use the TUNE procedure to accomplish this because it will change the known position of the rear mirror plate.

7. Make a 1 mm hole in a white business or index card using, for example, a thumb tack.

8. Place or hold the card near the tip of the front window stem. Position the card so the hole is centered on the violet plasma glow from the tube when viewed from the front of the head. Refer to Figures 7-9 and 7-10.

10. Using a 1/8 inch Allen wrench, rotate the Vertical and/or Horizontal Output Coupler Mirror Plate Adjusts until the reflected spot from the output coupler and plasma glow are centered on the hole of the card. (Refer to Figure 5-10 for the location of the adjustment screws.)

11. Remove the card from the front window stem.

12. If lasing is immediately observed, peak up the output power preliminarily using only the Vertical and/or Horizontal Output Coupler Mirror Plate Adjusts. Replace the front transition tube and dust shield bellows using the appropriate procedures described in the previous section titled: CARE AND CLEANING OF OPTICS: Output Coupler: Bayonet Mounted OC. Proceed to peak up the power using only the Vertical and/or Horizontal Output Coupler Mirror Plate Adjusts. Skip the next step and continue with step 14.

13. If lasing was not immediately observed of if the procedure to observe the retroreflection out of the rear of the system will not be performed, replace the front transition tube and dust shield bellows using the appropriate procedures described in the previous section titled: CARE AND CLEANING OF OPTICS: Output Coupler: Bayonet Mounted OC.

    If the procedure to observe the retroreflection out of the rear of the system will be performed, skip to step 7 of that procedure.

14. Initiate the TUNE procedure to search for or optimize lasing using the motorized rear mirror plate. Alternatively, if it is necessary, select the appropriate wavelength using the "Wavelength Menu" from the remote or use external computer control to specify wavelength (Command: Wavelength = n). If lasing is not established, refer to Chapter Nine, Troubleshooting.

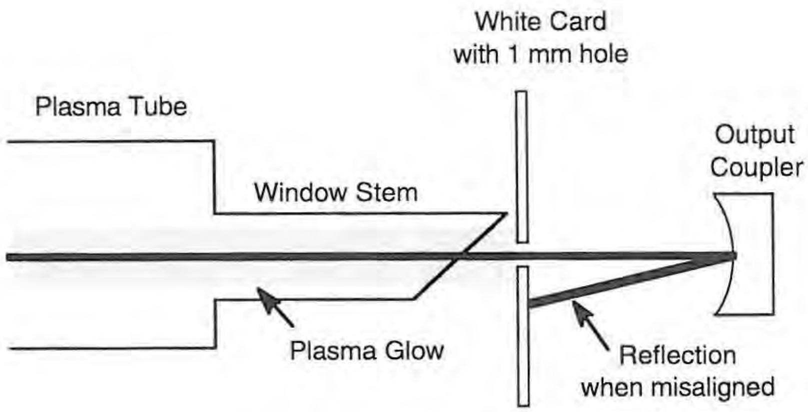


Figure 7-9. Setup For Observing Retroreflection At Anode (Front) Window

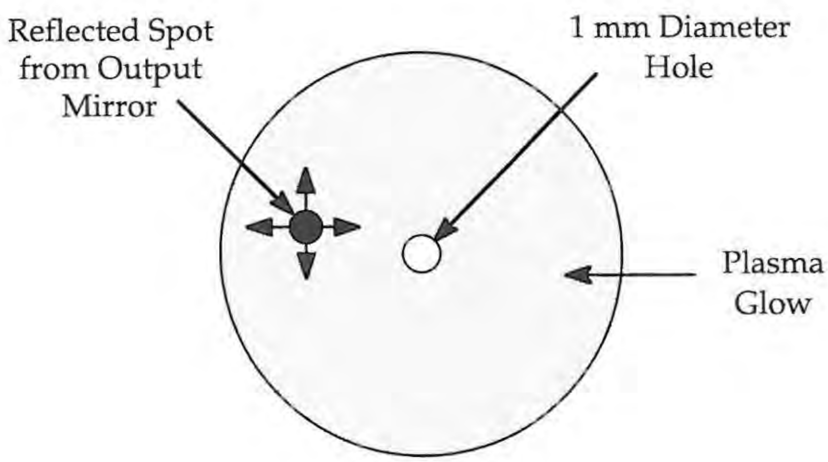


Figure 7-10. Translate Reflected Spot on White Card Vertically and/or Horizontally

15. Once lasing at the desired wavelength has been established, it may be desirable to perform the appropriate procedures described in the subsequent section: MIRROR ALIGNMENT PROCEDURES: Walk-In Procedure, to align the output coupler and high reflector with respect to the bore of the plasma tube for maximum available output power and best possible transverse laser mode.

    It may also be desirable to check and/or correct the alignment of the automatic aperture using the appropriate procedures described in the subsequent

section and related sub-sections: APERTURE ALIGNMENT PROCEDURE.

16. Select the desired automatic aperture position and regulation mode and setting. Turn PowerTrack On.

RETROREFLECTION AT REAR OF SYSTEM:

The following procedure should be used to observe the retroreflection out of the rear of the system. If the previous anode window retroreflection procedure has been executed, skip the first six steps and continue with step 7. Select the appropriate parts of the procedure that are applicable to the system type: sealed mirror or two-widowed.

1. Turn PowerTrack Off, operate in Current Regulation Mode, and set the automatic aperture to the OPEN position. It is advantageous to operate at a maximum tube current when performing this procedure.

2. Turn off the laser and keyswitch but maintain facility electrical power during the heat exchanger cool down time period.

3. Remove the front laser head sub-cover.

4. Install the interlock defeat to the front bezel.

5. If the system is two-windowed, remove the front transition tube and dust shield bellows using the appropriate procedures described in the previous section titled: CARE AND CLEANING OF OPTICS: Output Coupler: Bayonet Mounted OC.

6. Restart the laser. Note: If laser has not been shut down and restarted, then the PowerTrack actuators may not be at their centered positions. Do not use the TUNE procedure to accomplish this because it will change the known position of the rear mirror plate.

7. Close the intracavity shutter.

8. Install the multiline rear mirror holder in the system if it is not already installed. (An installed multiline holder without its mirror carrier ensures that the rear transition tube will not interfere with the plasma glow as it exits the rear of the head.)

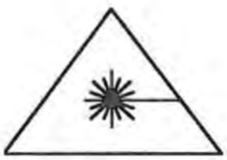
9. Unscrew the small knurled cap on the multiline rear mirror holder taking care not to release the entire assembly from its bayonet mount.

10. Pull out the small cylindrical mirror carrier.

11. Mount a white card or piece of paper approximately 4 to 5 feet (1.2 to 1.5 m) from the rear of the laser head.

12. Open the intracavity shutter.

13. Observe the violet plasma glow on the white card or piece of paper at the rear of the head. The retroreflection, if present, will be seen as a circular area of higher intensity that may fluoresce as a white-violet color. Dim room lights may aid in the observation.



Never look into the plasma tube unless the laser is de-ionized. Even when not lasing, the UV discharge of the tube can cause eye damage.

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14. If the retroreflection at the anode window has been aligned, repeatedly pass a card through the intracavity space between the output coupler and anode window and observe the plasma glow on the white card or paper at the rear of the head. If the retroreflection can be seen, skip the next two steps and proceed to step 17.

15. If the system is sealed mirror or if the preliminary alignment of the retroreflection at the anode (front) window has not been performed, use a 1/8 inch Allen wrench and turn the Vertical Output Coupler Mirror Plate Adjust 2 to 3 rotations counterclockwise to provide adequate range for rocking of the front mirror plate. (Refer to Figure 5-10 for the location of the adjustment screw.)

    If the retroreflection at the anode window has been aligned, turn the Vertical Output Coupler Mirror Plate Adjust 1 to 2 turns counterclockwise.

16. Grasping the front mirror plate near the Vertical Output Coupler Mirror Plate Adjust, pull the front mirror plate towards the front of the head and then carefully let it return to its original position. This is similar to the rocking of the front mirror plate described in the

previous Vertical Search Procedure section except that the rocking motion should be performed much more slowly here. Observe the plasma glow on the white card or paper at the rear of the head for the presence of the retroreflection. If no retroreflection is observed, rotate the Horizontal Output Coupler Mirror Plate Adjust very slowly in one direction while slowly rocking the front mirror plate. (Refer to Figure 5-10 for the location of the adjustment screw.) Watch carefully for a retroreflection

If you do not observe a retroreflection after rotating the Horizontal Output Coupler Mirror Plate Adjust three full turns in one direction, reverse the turning direction of the Horizontal Adjust and repeat the scanning process until a retroreflection is observed. Patience is required because it is not unusual to scan horizontally back and forth several times before the retroreflection is observed. It may be necessary to realign the output coupler for retroreflection at the anode window, as described in the previous procedure, to establish a default starting point for continuation of this procedure.

When the retroreflection is observed, rotate the Vertical Output Coupler Mirror Plate Adjust clockwise while continuing to rock until the retroreflection is approximately centered in the plasma glow.

17. With the retroreflection visible, slowly rotate the Vertical and/or Horizontal Output Coupler Mirror Plate Adjusts until the retroreflection attains maximum intensity. This usually, but not always, occurs when the retroreflection is centered in the plasma glow. Repeated passing of a card through the intracavity space between the output coupler and anode window in a two-windowed system or continuation of slight rocking in a sealed mirror system will maintain visibility of the retroreflection.

18. If the system is two-windowed, replace the front transition tube and dust shield bellows using the appropriate procedures described in the previous section titled: CARE AND CLEANING OF OPTICS: Output Coupler: Bayonet Mounted OC.

20. Close the intracavity shutter.

21. Re-insert the high reflector mirror carrier, with the appropriate optic installed, and orientate it rotationally such that the small dowel pin on the mirror carrier mates

with the slot in the mirror holder. Screw on the knurled cap.

22. Open the intracavity shutter.

23. Initiate the TUNE procedure to search for or optimize lasing using the motorized rear mirror plate. Alternatively, if it is necessary, select the appropriate wavelength using the "Wavelength Menu" from the remote or use external computer control to specify the wavelength (Command: Wavelength = n). If lasing is not established, refer to Chapter Nine, Troubleshooting.

24. Once lasing at the desired wavelength has been established, perform the appropriate procedures described in the subsequent section: MIRROR ALIGNMENT PROCEDURES: Walk-In Procedure, to align the output coupler and high reflector with respect to the bore of the plasma tube for maximum available output power and best possible transverse laser mode.

25. Check and/or correct the alignment of the automatic aperture using the appropriate procedures described in the subsequent section and related sub-sections: APERTURE ALIGNMENT PROCEDURE.

26. Convert the system to the single line configuration, if desired, using the appropriate procedures described in the previous section: MULTILINE/SINGLE LINE SWAP.

27. Select the desired automatic aperture position and regulation mode and setting. Turn PowerTrack On.

Walk-In Procedure

Lasing in the multiline cavity configuration implies that the mirrors are essentially parallel, but does not guarantee that they are optically aligned to the bore of the plasma tube. The same statement holds for a system operating in the single line configuration where the prism and high reflector together act as a single mirror at one end of the cavity. Figure 7-11 shows a multiline laser that was improperly aligned initially, that is, the optical and tube axes were not collinear. Maximum available output power and best possible transverse mode are usually coexistent and can be attained by aligning the mirrors such that these axes coincide. This alignment can be achieved by the Walk-In Procedure described below.

Please note in the following procedure that the Vertical and Horizontal High Reflector Mirror Plate Fine Adjusts have finite ranges corresponding to approximately 3/4 of a turn each. (Refer to Figure 5-10 for the location of the fine adjustment knobs.) If at any time during this procedure the limit of the either adjustment range is encountered, center both to their respective midrange positions and initiate the TUNE procedure to re-establish maximum output power and maximum fine adjustment range. Make adjustments gently and do not attempt to turn the fine adjusts beyond the ends of their ranges as system wavelength calibration could be corrupted.

1. Turn PowerTrack Off, operate in Current Regulation Mode, and set the automatic aperture to the OPEN position. It is advantageous to operate at a maximum tube current when performing this procedure. Initiate the TUNE procedure to automatically maximize the output power. Observe the initial power and, if possible, transverse laser mode.
2. Using a 1/8 inch Allen wrench, turn the Vertical or Horizontal Output Coupler Mirror Plate Adjust until the output power drops in half. (Refer to Figure 5-10 for the location of the adjustment screw.) Observation of the transverse laser mode will aid in determining which axis to adjust first.
3. Turn the High Reflector Fine Adjust of the same axis until the power is again maximized. Adjust to maximum power using both High Reflector Fine Adjusts.
4. If the output power is now greater than before, turn the Output Coupler Adjust of the same axis further in the same direction, then repeat step 3.
5. If the output power has decreased, turn the Output Coupler Adjust of the same axis in the opposite direction until the power drops in half, then return to step 3.
6. Repeat iterations of steps 3, 4 and 5 decreasing the amount of power that is detuned by the Output Coupler Adjust when the direction is changed, until re-peaking by the High Reflector Fine Adjusts produces an absolute power maximum.
7. When the output power is maximized, turn the Output Coupler Adjust of the other axis and repeat the trial-and-error adjustments (steps 2-6) to maximize power.

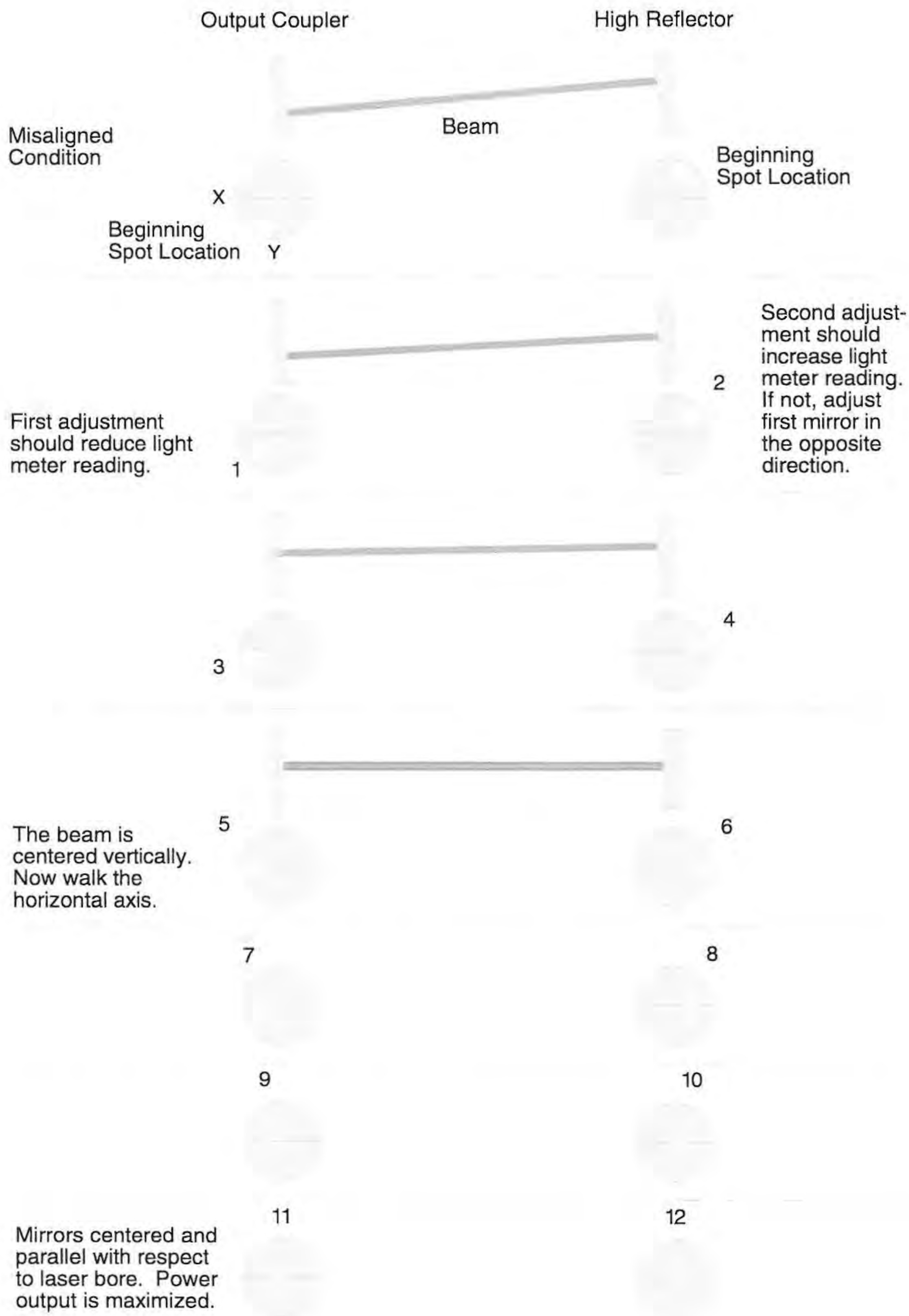


Figure 7-11. Walk-in Procedure Example

8. Iterate between the axes until the laser is at its maximum available power and displays the best possible transverse mode.
9. Check and/or correct the alignment of the automatic aperture using the appropriate procedures described in the subsequent section and related sub-sections: APERTURE ALIGNMENT PROCEDURE.

Figure 7-11. Walk-in Procedure Example

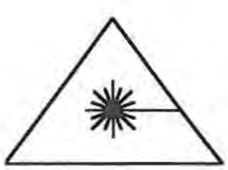
Aperture Alignment Procedure

The automatic aperture may need aligning after the Walk-In Procedure has been performed, if the aperture assembly has been removed from the head, or if the plasma tube position relative to the resonator has changed.

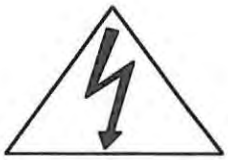
To check aperture alignment, turn PowerTrack Off. Set the automatic aperture position to the OPEN position using the remote and observe the output power and, if possible, the laser transverse mode. Systematically decrease the size of the aperture holes by selecting smaller numbered aperture positions (18 to 1). The output power should decrease gradually while maintaining good transverse mode as the lower aperture positions are selected.

If the automatic aperture is misaligned, the output power will drop dramatically or asymmetric diffraction rings will appear on the transverse mode as lower aperture positions are selected. At some point, the aperture may completely occlude the beam and lasing will cease.

The aperture uses a three-point positioning system as shown on Figure 7-12. The points correspond to three spring-loaded screws that enable all adjustments to be made with a 3/32 inch Allen wrench. One screw on the side of the assembly is the Vertical Aperture Adjust. The Horizontal and Pivot Aperture Adjust screws are used in a complimentary fashion to achieve horizontal alignment.



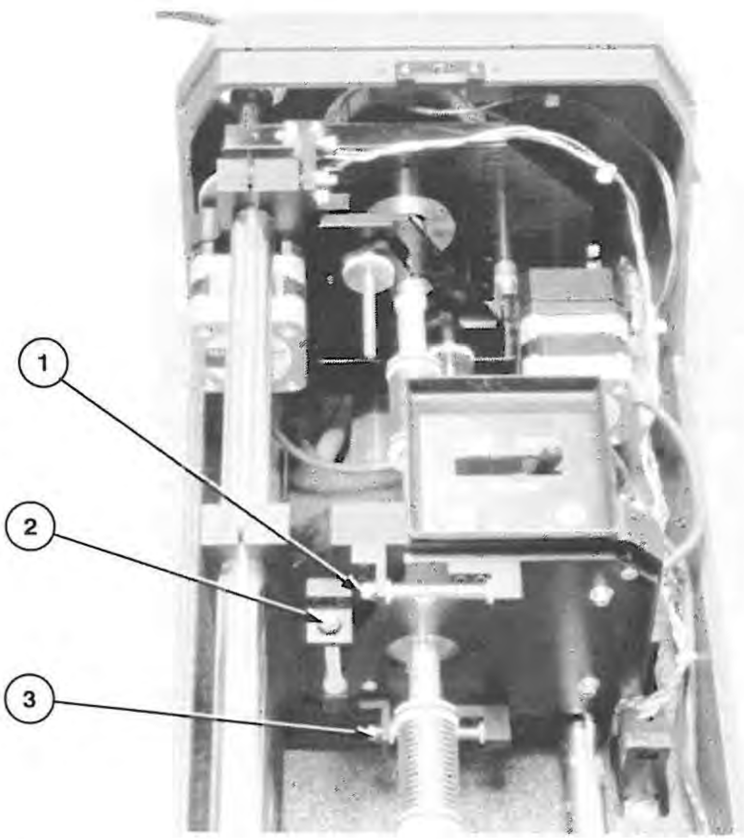
Operating the laser without the protective housing in place exposes the operator to hazardous laser and collateral radiation. Wear safety glasses that protect against the wavelengths employed.



Circuits in the laser head operate at high voltages. HIGH VOLTAGES CAN BE LETHAL. Use EXTREME CAUTION whenever operation without the laser head sub-covers is required.

Align the automatic aperture as follows:

1. Turn off the laser and keyswitch but maintain facility electrical power during the heat exchanger cool down time period.
2. Remove the rear laser head sub-cover.
3. Install the interlock defeat to the rear bezel.
4. Restart the laser.



1. Horizontal aperture adjust
2. Vertical aperture adjust
3. Pivot aperture adjust

Figure 7-12. Automatic Aperture, Showing Adjustment Screws

5. Turn PowerTrack Off, operate in Current Regulation Mode, and set the automatic aperture to the OPEN position. It is advantageous to operate at a maximum tube current when performing this procedure.

6. Perform the Walk-In Procedure to ensure that the beam is aligned within the plasma tube bore.

7. Observe the output power and, if possible, transverse mode at the OPEN aperture position.

8. Select aperture position 18 and carefully align the aperture using the adjustment screws to maximize power and maintain good transverse mode. Asymmetry in the transverse mode will indicate whether vertical or horizontal alignment is required. Be sure to use the Pivot Aperture Adjust in conjunction with the Horizontal Aperture Adjust for horizontal alignment to provide for maximum adjustment range. The output power should equal to or greater than that observed at the OPEN position.

9. Select aperture position 10 and carefully align the aperture using the adjustment screws to maximize power and maintain good transverse mode.

10. If desired, initiate an automatic search for the aperture position resulting in TEM_{00} or select the desired aperture position for system operation and align aperture the for maximum power and best possible transverse mode. Initiate another TEM_{00} search, if applicable, and recheck alignment to ensure proper system operation.

11. Check alignment for gradual power decrease as the aperture is decrease from the OPEN to the smallest aperture position.

12. Shut down the laser, remove the interlock, and reinstall the laser head sub-cover.

13. Restart laser. Select the desired automatic aperture position and regulation mode and setting. Turn PowerTrack On.

Measurement of the Transverse Mode

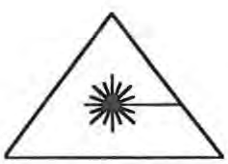
Some procedures in this manual require inspection of the transverse spatial profile of the laser beam, sometimes called the transverse mode. The simplest profiles have standard designations (e.g., TEM_{00}, TEM_{01^*}). More information on the transverse modes is given in Chapter Ten, Theory of Operation.

Several methods are available for checking the spatial profile of laser beams, varying widely in cost and accuracy. These are:

- Visual inspection,
- Use of the integrated TEM_{00} detector,
- Scanning and recording the beam intensity profile,
- Use of a Coherent Mode Master™,
- RF spectrum analysis of the beat frequencies between cavity transverse modes.

For Sabre alignment and maintenance, visual methods usually provide adequate diagnostic information.

Visual inspection of the spatial profile requires expanding the beam to a diameter of 10 cm (4 inch) or more so that details can be easily seen. This is done using a lens or mirror of focal length 1.5 to 3 cm (0.5 to 1 inch) to project the beam onto a wall or screen.



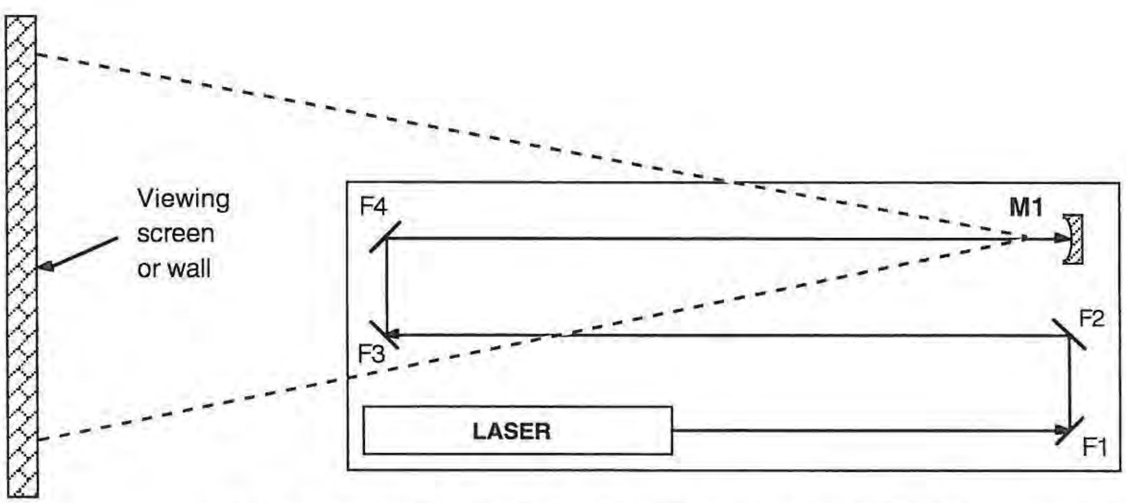
It is unsafe to hold the inspection optic in the beam by hand. CLOSE the laser shutter before placing the optic in the beam; do not open the shutter until the optic is secure.

Use extreme caution when projecting the laser beam in this fashion. The expanded beam is sufficiently intense to cause severe ocular damage. All personnel in the area must wear safety glasses.

When performing certain cavity alignment procedures, such as the Walk-In or Aperture Alignment Procedures, the transverse mode may be observed in the so called "near field" where the expanding optic is located close to the laser head. Observation of the projected transverse mode will aid in determining which axis, vertical or horizontal, to concentrate alignment on. The "near field" mode also is useful in determining whether or not to clean any of the optics.

While this method is easy to implement, misleading results, concerning the actual transverse mode oscillating, will occur if the inspection optic is placed too close to the output coupler. Intracavity aperture diffraction of laser light will impose a pattern of dark concentric rings on the output beam. The contrast between these rings and the surrounding bright areas decreases with distance from the laser head. To avoid these rings and to truly determine which transverse mode is oscillating, place the optic at least 5 meters (16.5 ft.) from the output coupler in the "far field".

Diffraction rings produced by the laser aperture are not normally a cause for concern. These rings do produce intensity distortions in the transverse profile of the laser beam. But, these distortions disappear in the far field (e.g., as the beam propagates through space or, more commonly, as the beam is focused). The spatial profile viewed using the setup shown in Figure 7-13 will accurately represent the transverse intensity profile generally. This representation will be accurate even if the beam is focused to a spot at distances much closer to the laser.



F1-F4: Fold mirrors to extend optical path — M1: 2 cm radius of curvature mirror
Total path from laser head to M1: ≥ 5 meters

Figure 7-13. Far Field Mode Inspection

Operator's Manual

Chapter Eight
Single-Frequency Operation

COHERENT

Introduction

The INNOVA Sabre Ion Laser has three modes of single-frequency operation: Manual, ν-Track, and ModeTrack. Also included are two initialization routines for single-frequency optimization: ModeTune and ModeFineTune.

- Manual operation is the basic mode in which the etalon temperature and Z-axis cavity length servo position (Z-axis DAC) can each be manually set by the operator and held at fixed values. This mode is used during laser warm-up and when setting up the etalon or changing wavelength. Manual mode also allows the user to shift single-frequency operation, if desired, to a frequency not coincident with maximum gain, as set by ModeTune.
- ν-Track is an active stabilization loop that continuously adjusts the Z-axis DAC to track the etalon transmission curve which effectively eliminates laser cavity length changes and prevents frequency drift (and thus also mode hopping and power drift). ν-Track is the standard mode of operation recommended for immediate and long term single-frequency stability and mode-hop free operation.
- ModeTrack is an active stabilization loop that continuously adjusts the etalon temperature to track laser cavity drift and prevent mode hopping. ModeTrack may be used as an alternative to ν-Track when the laser is fully warmed up and environment temperature is stable. Also, if the laser frequency (cavity length) were controlled by or locked to an external source, ModeTrack might be used to lock the etalon to the frequency and prevent mode hops.
- ModeTune and ModeFineTune are automatic tuning routines that find and set the etalon temperature and Z-axis DAC to achieve maximum single-frequency output power.

This chapter will detail the procedures required for initial installation and alignment of the etalon, as well as describe each of the above modes and how to control them.

For a detailed theoretical background of the single-frequency cavity configuration, see Chapter Ten, Theory of Operation.

Special Considerations

Single-Frequency Verification

To ensure actual single-frequency operation requires the use of a scanning interferometer (Coherent Model 240 spectrum analyzer). If a scanning interferometer is not available, then it may be possible to attain single-frequency operation by tuning the etalon through a frequency range exceeding its free spectral range while observing the output power. Readjusting the etalon set temperature to the value that was observed at the maximum output power may correspond to single-frequency operation near the peak of the gain curve. This procedure may be done manually or automatically using the ModeTune and ModeFineTune routines described in the following sections.

Single-Frequency Operation at 488.0 nm

Due to the high gain of the argon 488.0 nm line, multiple longitudinal modes can lase simultaneously at high current levels with equal or greater power than when lasing in peak single-frequency mode. This may inhibit the ModeTune routine from correctly identifying the true single-frequency peak. For best results when operating at 488.0 nm, start ModeTune with the laser current set for 55 A or less. After ModeTune finds the peak, increase the current to the desired output power level. True single-frequency operation at 488.0 nm also requires single transverse mode operation which can be verified using a scanning interferometer. For special considerations concerning indications by the TEM_{00} detector, refer to Chapter Ten, Theory of Operation.

ModeTune Operation in Ultraviolet Wavelengths

Due to the low finesse of the UV etalon transmission curve, multiple longitudinal modes can lase simultaneously at high current levels with equal or greater power than when lasing in peak single-frequency mode. This may inhibit the ModeTune routine from correctly identifying the true single-frequency peak. For best results when operating in UV, start ModeTune with the laser current set for 55 A or less. After ModeTune finds the peak, increase the current to the desired output power level. At the peak, the aperture setting may also be increased to increase output power while maintaining TEM_{00}.

Single-Frequency Drift Stability

Single-frequency drift, without ν-Track active, is a direct function of laser cooling water temperature and ambient air temperature around the resonator. ν-Track can eliminate these effects, preventing drift, but only when the laser operating environment is maintained with the following minimal recommendations:

- Use Sabre heat exchanger with secondary loop water temperature set properly. See Chapter Four, Utility Requirements and System Installation, and Chapter Five, System Description and Control, for proper temperature setup of heat exchanger.
- Do not install laser in a location where extreme ambient air temperature fluctuations will occur. ν-Track can typically handle long term temperature changes of ±10 °C before running out of range. In a typical installation it is expected that less than a quarter of this range would be required.
- Always operate the laser with all head covers in place.

Single-Frequency Jitter Stability

Single-frequency jitter is a direct function of laser resonator vibration. To minimize frequency jitter, the following is recommended:

- Use heat exchanger with the secondary loop water flow rate set for the specified minimum of 22.7 lpm (6.0 GPM). See Chapter Four, Utility Requirements and System Installation, and Chapter Five, System Description and Control, for proper flow setup of heat exchanger.
- Install the laser head on a vibration free surface (optical table with vibration isolation is recommended).

Conversion Efficiency

The single-frequency power guarantee is 60% of the single line power specification for visible lines or 50% of the single line power specification for ultraviolet lines specified at time of purchase. See Chapter Two, System Specifications and Parameters, for Standard Power Specifications.

Actual single line TEM_{00} powers are typically greater than that specified. When setting up single-frequency operation, the output power expected should be at least 60% of the actual single line TEM_{00} power for visible lines or 50% of the actual single line TEM_{00} power for UV lines.

Interrelationship of PowerTrack and the Z-axis DAC

The electromagnetic actuators that are used by PowerTrack to orient the tilt angle of the output coupler are also utilized by several single-frequency operating modes to change the cavity length. The available ranges of the PowerTrack DACs and the Z-axis DAC are therefore interdependent. To determine the available range of the Z-axis DAC requires knowledge of the values of the PowerTrack DACs and vice versa. The maximum range of one will occur when the other is near its centered position.

The shaded region of Figure 8-1 shows the valid range of the Z-axis DAC as a function of the observed PowerTrack A or B DAC values. When PowerTrack is centered (PTDAC = 512), the maximum available range of valid Z-axis DAC is 300 to 3796. The PowerTrack A or B DAC which displays the greatest deviation from the centered position determines the current PTDAC shown on Figure 8-1. If the Z-axis DAC exceeds the valid range while in v-Track, an v-Track error will occur and the Manual etalon mode will be assumed. Manual control of the Z-axis DAC will be allowed only within the valid range. The other single-frequency routines that can change the cavity length, ModeTune and ModeFineTune, automatically calculate their respective available ranges based on the PowerTrack DAC values.

The shaded region of Figure 8-2 shows the valid range of operational PowerTrack as a function of the observed Z-axis DAC. When the Z-axis DAC is centered (ZDAC = 2048), the maximum available range of operational PowerTrack is 25 to 999. If system misalignment requires either the PowerTrack A or B DAC to exceed the valid range, then PowerTrack will be parked and a PowerTrack out of range condition will exist. For more information, refer to Chapter Five, System Description and Control.

The limits of valid operation have been set such that the Z-axis DAC will go out of range before the PowerTrack in order to maintain system alignment. The PowerTrack and Z-axis DAC settings are automatically centered each time the laser is started or when the TUNE procedure is initiated.

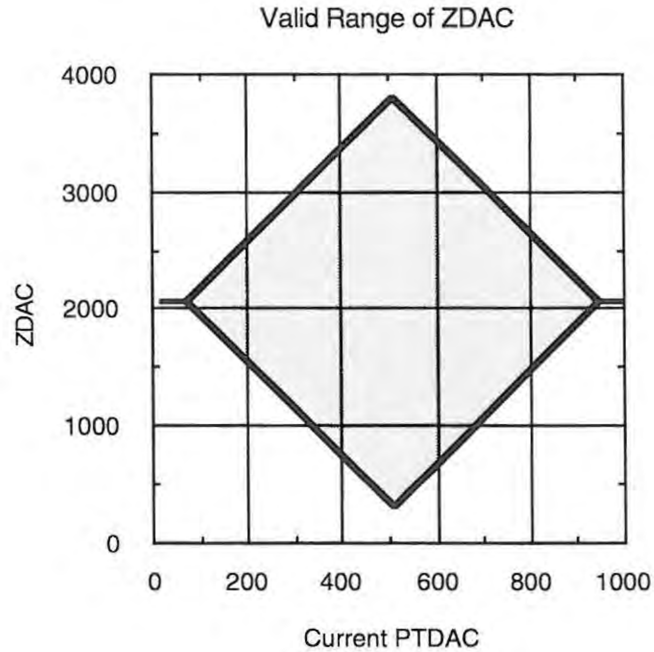


Figure 8-1. Valid Range of the Z-axis DAC

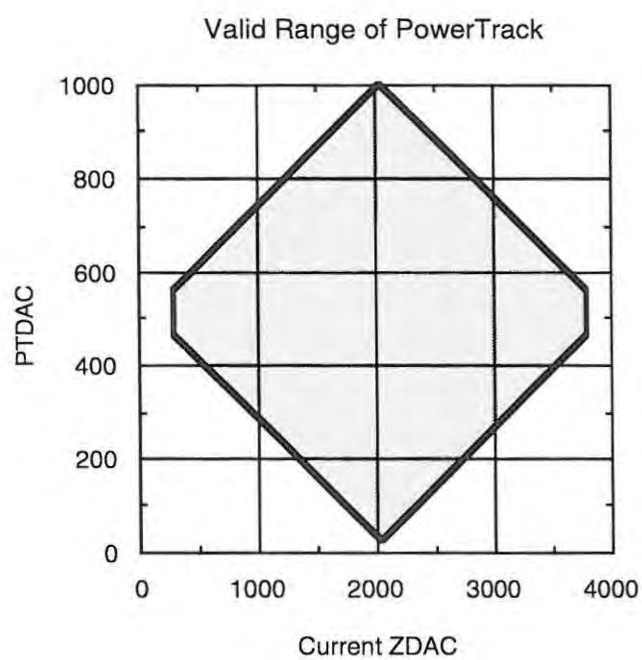


Figure 8-2. Valid Range of Operational PowerTrack

Sabre Etalon Mounting Bracket Installation

Use the following procedure to install the etalon oven mounting bracket and dummy etalon tube. The dummy etalon tube allows conversion to and from single-frequency operation without removing the etalon holder bracket.

This procedure is only required if the single-frequency option was purchased separately. If the single-frequency option was specified at the time of purchase of the laser system, the etalon oven mounting bracket and dummy etalon tube should already have been installed by factory technicians.

Circuits in the laser head and power supply operate at high voltages. HIGH VOLTAGES CAN BE LETHAL. Do not remove the main head cover or any internal safety covers for this procedure. Use EXTREME CAUTION whenever operating without the head sub-covers.

Operation of the laser without the protective housing in place will allow access to hazardous laser and collateral radiation. The laser housings should only be opened for the purposes of maintenance and service by qualified technicians cognizant of the hazards involved. Wear safety glasses which protect against the wavelengths used.

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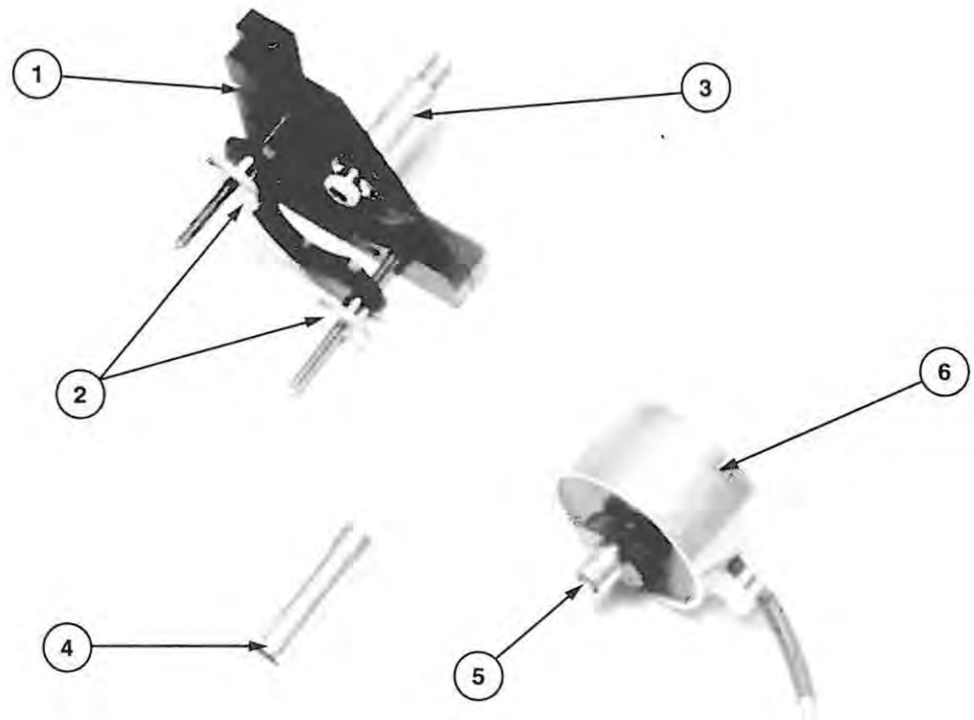
1. Turn the laser OFF.

2. Carefully unpack the etalon assembly, being careful to avoid touching the beam enclosure tubes on the etalon holder (Figure 8-3). The etalon assembly contains the etalon holder bracket with two mounting screws and the etalon oven. You will also need the etalon oven place holder tube called 'dummy etalon' which is already installed in the laser.

3. Close the intracavity shutter by sliding the lever to the CLOSE position.



1. Etalon oven holder bracket
2. Knurled nuts (2)
3. Beam enclosure tube (transition tube)
4. Dummy etalon tube
5. Stem
6. Etalon oven

Figure 8-3. Etalon Components Disassembled

4. Remove the high reflector mirror holder from the rear bayonet mount.

5. Remove the rear sub-cover from the laser head by sliding the spring loaded latch and lifting it off.

6. Carefully ease the rear bellows dust shield forward toward the aperture motor and onto the rear aperture seal tube (Figure 8-4). Try not to disturb the aperture wheel orientation.

7. Carefully remove the rear seal tube that was attached to the bellows by sliding it forward. This is the dummy etalon tube and will be re-installed with the etalon holder bracket.

8. Remove the transition tube and thin mounting plate assembly by removing the two screws that secure the it to the rear resonator web. Use a 7/64 in. Allen wrench.

9. Install the etalon oven holder bracket by securing it to the resonator web using the two mounting screws. Use a 7/64 in. Allen wrench to tighten these screws securely (refer to Figure 8-5 for bracket location).

10. Re-install the dummy etalon tube by sliding it onto the transition tube in the etalon holder bracket.

11. Slide the bellows dust shield back onto the dummy etalon tube. The rear sub-cover can be re-installed at this time.

12. Re-install the high reflector mirror holder.

13. Open the intracavity shutter by sliding the lever to the OPEN position.

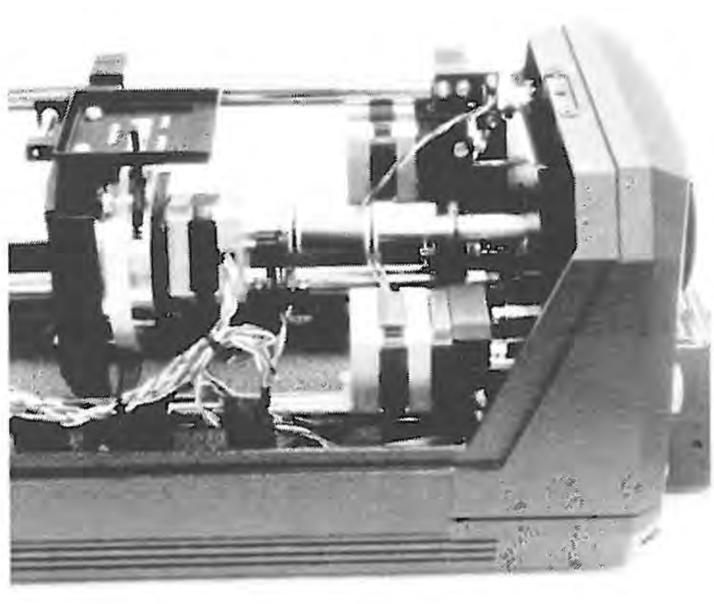


Figure 8-4. Laser Head Before Etalon Oven Bracket Installed

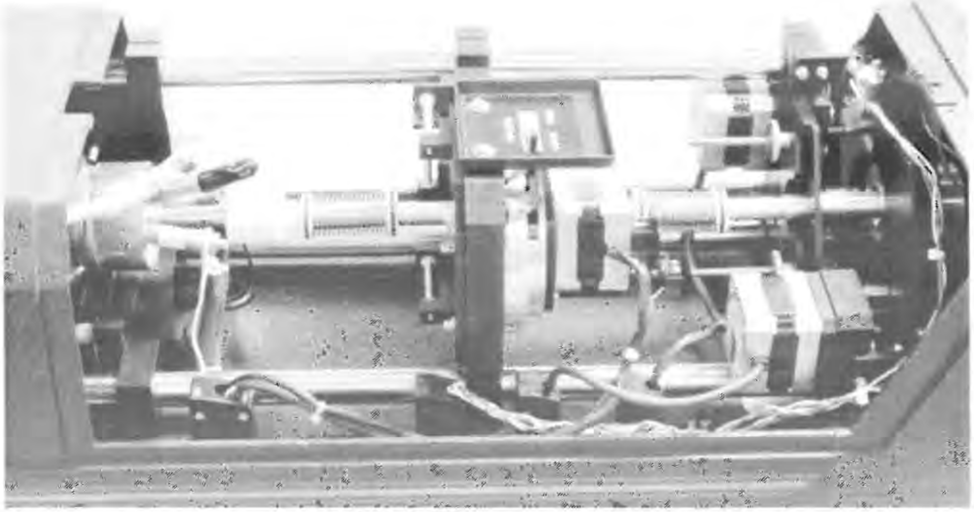


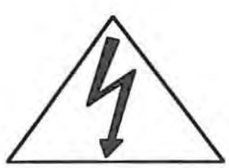
Figure 8-5. Laser Head With Etalon Oven Bracket Installed

Sabre Etalon Installation

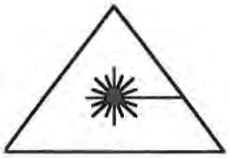
Use the procedure below to install the etalon. Also refer to the following sections on ModeTune, ModeFineTune, ν-Track, and ModeTrack for additional information about single-frequency operation.

Refer to Table 8-1 to verify the proper etalon optic required.

To ensure true single-frequency operation and aid alignment of the etalon, a Coherent Model 240 spectrum analyzer (scanning interferometer), a Model 251 controller, an uncoated beamsplitter and an oscilloscope are required. The last section of this installation procedure describes the setup and alignment of the spectrum analyzer to verify true single-frequency operation.



Circuits in the laser head and power supply operate at high voltages. HIGH VOLTAGES CAN BE LETHAL. Do not remove the main head cover or any internal safety covers for this procedure. Use EXTREME CAUTION whenever operating without the head sub-covers.



Operation of the laser without the protective housing in place will allow access to hazardous laser and collateral radiation. The laser housings should only be opened for the purposes of maintenance and service by qualified technicians cognizant of the hazards involved. Wear safety glasses which protect against the wavelengths used.

Have all the necessary equipment on hand and proceed as follows:

1. Turn the laser OFF.

2. Remove the rear sub-cover from the laser head by sliding the spring loaded latch and lifting it off. Install the interlock defeat.

3. Turn the laser ON and install the single line rear mirror holder appropriate for the desired optic set. Set the laser for single line operation at the desired wavelength (refer to Chapter Five, System Description and Control, and Chapter Seven, Optics and Alignment, for the necessary procedures).

Table 8-1. Etalon Optic

Gas Type	Wavelengths	Optic Thick-ness	Coated/ Uncoated	Optic Part #	Option Order #
Argon	333.6 - 385.8 nm	7.95 mm (0.313 in.)	Uncoated	0167-399-02	0166-498-01
Argon	454.5 - 514.5 nm	10.16 mm (0.400 in.)	Coated	0502-908-01	0166-498-00
Argon	528.7 nm	10.16 mm (0.400 in.)	Uncoated	0502-908-02	0166-498-02
Krypton	337.5 - 482.5 nm	10.16 mm (0.400 in.)	Uncoated	0502-908-02	0166-498-02
Krypton	520.8 - 676.4 nm	10.16 mm (0.400 in.)	Coated	0502-908-01	0166-498-00

4. If not already installed, install the etalon oven mounting bracket and dummy etalon tube using the procedure above.

5. Set the automatic aperture to the OPEN position. Refer to Chapter Five, System Description and Control, if unfamiliar with this procedure.

6. Set the laser to full current in Current Regulation Mode and allow the laser to warm-up at least 30 minutes.

Calibrate PowerTrack at this time, before turning PowerTrack off, if calibration is necessary (refer to Chapter Five, System Description and Control).

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7. Turn PowerTrack OFF (Refer to Chapter Five, System Description and Control, if unfamiliar with this procedure).

8. Activate TUNE to center PowerTrack and optimally align the rear mirror plate. Refer to Chapter Five, System Description and Control, if unfamiliar with this procedure.

9. Select the aperture setting for TEM_{00} mode operation. Refer to Chapter Five, System Description and Control, if unfamiliar with this procedure.

   Note: For 488.0 nm argon operation, an indication by the system of TEM_{00} does not necessarily guarantee single transverse mode oscillation. Once single longitudinal mode oscillation is achieved, verify single transverse mode oscillation with a scanning interferometer and aperture down if necessary. For more information, refer to Chapter Ten, Theory of Operation.

   Check aperture alignment and adjust if necessary using the procedures described in Chapter Seven, Optics and Alignment Procedures.

10. Record the output power and verify that it meets single line specifications.

11. Close the intracavity shutter by sliding the lever to the CLOSE position.

12. Carefully unpack the etalon oven (Figure 8-3). The etalon oven contains the etalon optic.

13. Clean the etalon optic using the Drop-and-Drag Method described in Chapter Seven, Optics and Alignment Procedures.

14. Place the etalon into the etalon oven. Insert the O-ring and stem and secure to the oven with the knurled nut.

15. Carefully ease the rear bellows dust shield forward toward the aperture motor and onto the rear aperture seal tube (Figure 8-4). Try not to disturb the aperture wheel orientation.

16. Carefully remove the dummy etalon tube that was attached to the bellows by sliding it forward.

17. Loosen the two knurled nuts of the etalon holder bracket. Place the etalon oven in the bracket and push it toward the back plate so it engages the transition tube. Hold the oven in place while tightening the two knurled nuts evenly (Figure 8-6). Run the cable along the inside of the head and plug it into the connector in the baseplate labeled 'ETALON OVEN'. Attach cable to clip on aperture mount. Route the cable so it does not touch the cover, any part of the tube, dust shield or stem when installed.

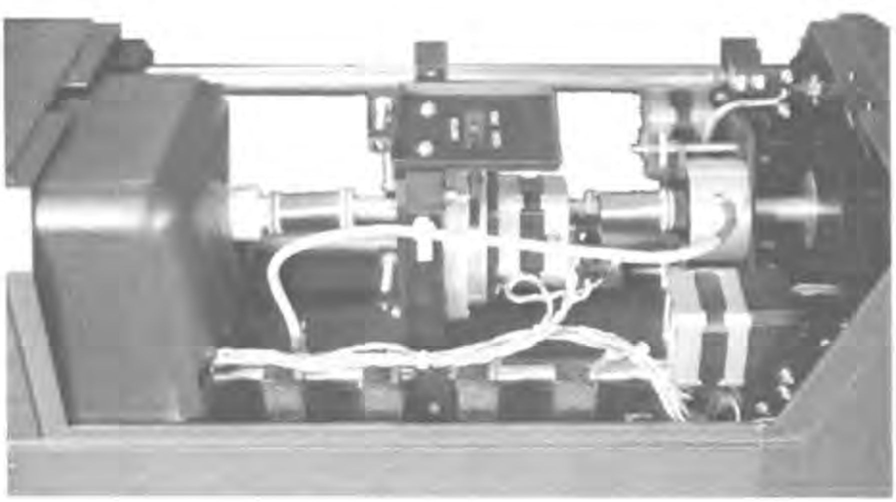


Figure 8-6. View of Rear of Laser Head Showing the Etalon Assembly Installed

18. Slide the rear bellows dust shield back onto the etalon stem.

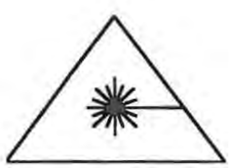
19. Open the intracavity shutter, if desired, and allow the etalon to warm up. Verify proper oven operation by navigating the menu tree as shown in Figure 8-8. The top level of the "Etalon Menu" will display 'No etalon' until the etalon temperature exceeds 25 °C.

    When the display showing the set etalon temperature and Z-axis DAC appears, navigate the menu tree as shown in Figure 8-8 to get to the Manual etalon temperature selection menu. The actual etalon temperature equals the set temperature plus the error. Alternatively, use external computer control (Queries: Print Etalon Temperature or Print Etalon) to get the actual temperature.

    The actual etalon temperature should increase rapidly, and then stabilize at the set temperature. During this period (approximately ten minutes), the output power will fluctuate as the etalon heats up if the intracavity shutter is open.

Aligning the Etalon

Use the following procedure to adjust the etalon for maximum single-frequency power: This procedure is presented as a continuation of the previous section, Sabre Etalon Installation.



When carrying out optical alignment procedures, reflected beams may exit the laser cavity. Ensure that laser safely glasses or goggles, which protect against the wavelengths used, are worn at all times during operation of the laser.

20. Turn the laser OFF.

21. Carefully ease the forward aperture bellows dust shield from the cathode (rear) Brewster window towards the aperture assembly and onto the forward aperture seal tube (Figure 8-6).

22. Open the intracavity shutter, if necessary, by sliding the lever to the OPEN position.

23. Turn the laser ON.

24. Hold a white card or sheet above the head above the cathode (rear) Brewster window so that the reflected spots from the window appear on the card. If the etalon is not completely perpendicular to the intracavity beam, or if the etalon is not grossly misaligned, a series of spots will be seen on the card. These spots are multiple reflections from the two surfaces of the etalon.

25. Make sure that PowerTrack is OFF. Using a 1/8 in. Allen wrench, adjust the vertical and horizontal etalon tuning screws (Figure 8-7) so that the reflected spots on the card superimpose and power is maximized. When the reflected spots are coincident, the intensity may get noticeably brighter (flashes) and the output power should be near the value recorded in step 10.

26. Turn the laser OFF.

27. Carefully ease the bellows dust shield forward onto the cathode Brewster window stem.

28. Remove the interlock defeat and install the rear sub-cover.

29. Turn the laser ON.

1 Etalon Horizontal Tilt   2 Etalon Vertical Tilt

Figure 8-7. Etalon Tilt Adjustment

30. Using very fine adjustments, continue to adjust the two etalon tuning screws for maximum output power. The power achieved should be the same or more than the power recorded in step 10. The etalon will now be perpendicular to the intracavity beam acting as a rear mirror, resulting in a smaller laser cavity inside the main laser cavity. This position of the etalon is called flash.

    At flash, the spectrum analyzer output on the oscilloscope will typically display what appears to be a "continuum" of equal amplitude, closely spaced, longitudinal modes.

31. Turn the vertical etalon tuning screw 1/4 turn clockwise off flash. At this etalon tilt angle single-frequency operation is assured while walk-off losses are minimized.

32. Set the laser for 50 A in Current Regulation Mode to assure best results of ModeTune and allow a few minutes for the internal head temperature to stabilize.

33. Temperature tune the etalon for maximum single-frequency power by activating ModeTune. Refer to the ModeTune section later in this chapter and Figure 8-10, with the "ModeTune" parameter selected, to activate ModeTune from the remote.

    ModeTune will turn on PowerTrack and automatically switch to ModeFineTune and then ν-Track for active single-frequency stabilization. This should take approximately 20 minutes.

    For visible wavelengths, the power achieved should be greater than 60% the power recorded in step 10; for UV wavelengths, the power achieved should be greater than 50% the power recorded in step 10. Light Regulation Mode or a new current level may now be selected.

The single-frequency power guarantee is 60% of the single line power specification for visible lines or 50% of the single line power specification for ultraviolet lines specified at time of purchase. See Chapter Two, System Specifications and Parameters, for Standard Power Specifications.

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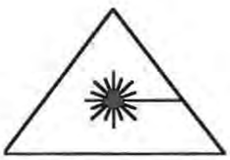
34. Set up and align the spectrum analyzer to check and monitor single-frequency operation.

Aligning the Spectrum Analyzer

Use the following steps to align the spectrum analyzer:

The following sequence is required to reduce the intensity of the beam entering the spectrum analyzer, because powers of approximately 5 mW saturate the photodetector and powers above 1 W damage the optics within the spectrum analyzer.



When carrying out optical alignment procedures, ensure that laser safely glasses or goggles, which protect against the wavelengths used, are worn at all times during operation of the laser.

1. Insert an uncoated beam pick-off in the path of the output beam, then place the Model 240 beam pick-off in the path of the reflected beam.
2. Connect the side BNC jack of the spectrum analyzer to the RAMP OUT BNC jack of the Model 251 controller.
3. Connect the BNC jack on the rear of the spectrum analyzer to the vertical channel of the oscilloscope.
4. Connect the SCOPE TRIG. BNC jack of the Model 251 controller to the external input of the oscilloscope and set its triggering source to external.
5. Put the REFERENCE SOURCE switch located at the rear of the Model 251 driver in the INT. position. Set the RISE TIME to 10 ms and the SWEEP EXPANSION to X1. Adjust the OFFSET knob fully clockwise to 200 V and the AMPLITUDE knob fully clockwise to 250 V.
6. On the oscilloscope, set the horizontal (time) scale to 0.5 ms/div and the vertical (voltage) scale to 5 mV/div.
7. With the beam passing through the center of the Model 240 beam pick-off, observe the beam path parallel to the body of the spectrum analyzer. Look for a bright spot in this beam path reflected from the cavity internal to the

spectrum analyzer. It may be necessary to rotate the beam pick-off or translate and/or angularly adjust the assembly to observe the bright reflected spot.

Note: It is not desirable to retroreflect this beam back into the laser cavity, especially when operating with UV wavelengths, as this unwanted feedback may perturb single-frequency operation.

Use the angular adjustments to align the spectrum analyzer until peaks appear on the oscilloscope trace.

8. Adjust the OFFSET and the AMPLITUDE knobs of the Model 251 driver so that at least two peaks are visible on the screen of the oscilloscope.

9. Using the angular micrometer knobs adjust the spectrum analyzer to maximize the peaks on the oscilloscope taking care not to retroreflect into the main laser cavity. Refer to the Model 240 spectrum analyzer operating manual.

If there is unequal spacing between the peaks on the oscilloscope, then the laser has not yet achieved single-frequency. These additional peaks could be either higher order transverse modes or unwanted longitudinal modes. Higher order transverse modes normally appear when the aperture has not been set correctly and can be eliminated by reducing the aperture size. Unwanted longitudinal modes appear when the peak of the etalon transmission curve is not coincident with the peak of the laser gain curve. To eliminate these modes, or to maximize single-frequency power, temperature tune the etalon as in step 33 of the previous section titled: Aligning the Etalon.

Single-Frequency Control Modes

The INNOVA Sabre Ion Laser has three modes of single-frequency operation: Manual, ν-Track, and ModeTrack. Also included are two initialization routines for single-frequency optimization: ModeTune and Mode Fine Tune. This section describes each mode and routine in detail and describes how they are controlled.

In typical operation, the single-frequency user leaves the keyswitch ON overnight to maintain the etalon thermal stabilization. The next morning, the user turns on the laser and allows it to warm-up for 5 minutes in Manual mode and Current Regulation with PowerTrack engaged. After initial warm-up, the operator would typically engage ν-Track. The

operator may also engage ModeFineTune or ModeTune. ModeTune would coarsely optimize the single-frequency power, then engage ModeFineTune for fine peaking. ModeFineTune would then automatically engage ν-Track. Once ν-Track has engaged, the user can set the laser to Light Regulation Mode for increased power stability. The last section of the chapter will describe recommended daily operation turn-on and shut-down procedures.

Reading the Single-Frequency Mode

To read the single-frequency mode, navigate the menu tree as shown in Figure 8-8 to the top level of the "Etalon Menu". In the "Etalon Menu" level, the etalon mode is displayed on the first line. The etalon set temperature (°C) and Z-axis DAC setpoint are displayed on the second line. The Z-axis DAC setpoint will change automatically when ν-Track is active. The set temperature will change automatically when ModeTrack is active. The etalon temperature and Z-axis DAC setpoints will change automatically while ModeTune or ModeFineTune is scanning.

The etalon mode displayed on the first line will indicate one of the following:

Etalon:Manual...............Manual mode.

Etalon:ModeTune.........ModeTune active.

Etalon:FineTune...........ModeFineTune active.

Etalon:NuTrack.............ν-Track active.

Etalon:ModeTrack........ModeTrack active.

Etalon:MTuneErr..........Manual mode,
ModeTune error occurred.

Etalon:FTuneErr...........Manual mode,
ModeFineTune error occurred.

Etalon:NTrackErr..........Manual mode,
ν-Track error occurred.

Etalon:MTrackErr.........Manual mode,
ModeTrack error occurred.

If no etalon is installed (or the oven is inoperative), this menu will display "No Etalon" and all submenus will be inactive. When the power supply is first turned on or when the etalon oven is first plugged into the head, the "No Etalon" display will appear for a few seconds until the oven temperature is greater than 25 °C.

Alternatively, the single-frequency mode can be accessed through external computer control (Queries: Print Etalon Mode or Print Emode).

Manual Operation

Manual operation is the basic mode in which the etalon temperature and Z-axis cavity length servo position (Z-axis DAC) can each be manually set by the operator and held at fixed values. In this mode, the longitudinal mode positions are fixed to the resonator cavity length and the etalon transmission curve remains fixed with respect to the laser gain curve (see Chapter Ten, Theory of Operation).

As the temperature inside the laser head changes, the cavity length will increase or decrease and the frequency of the longitudinal modes will change. As the lasing mode drifts off the center of the etalon transmission curve, the laser output power can drop as much as 20%. Then suddenly the laser frequency will mode hop a multiple, usually one, of 75 MHz (the mode spacing for the Sabre) to a neighboring mode that is closer to the peak of the etalon transmission curve. The output power will return to maximum after each mode hop. With PowerTrack, power may drop even more before a mode hop occurs. When the laser is properly aligned (as described in the previous section, Sabre Etalon Installation) and lasing in single-frequency in Manual mode, the output power should follow a sawtooth pattern (Figure 8-11) with time, dropping as much as 20% or more before each mode hop. When the laser is first started, even with the etalon fully warmed up, mode hops can occur every few minutes. The number of mode hops will decrease as the laser head warms up and stabilizes. With PowerTrack, the envelope of the power after each mode hop should be constant since mirror alignment is maximized. Once warmed up, mode hops can still occur if the temperature of the ambient air or cooling water changes by as little as 1.0 °C.

It is not recommended to use Light Regulation when operating in Manual mode unless the laser is well warmed-up and stabilized. Otherwise the laser current will rise and fall appreciably with mode hops. This may result in Light Regulation running out of range as well as preventing thermal stabilization of the laser.

When to Use Manual Mode

For best results, always allow the laser to warm-up 5 minutes in Manual mode and Current Regulation mode before starting ν-Track or ModeTrack.

Whenever aligning the etalon (as described above), set the etalon to Manual mode and turn PowerTrack off. After alignment, run ModeTune to temperature tune the etalon and engage ν-Track.

The system will automatically switch to Manual mode whenever TUNE is engaged, a new wavelength is requested, or the laser is shut off.

Manual mode can be used to directly set the etalon temperature when a new wavelength is selected if the temperature is known from a previous ModeTune run. Manual mode may also be used to shift single-frequency operation to a specific required frequency not coincident with maximum gain. In either case, the steps below should be followed.

1. Set the etalon temperature to the desired value or adjust until the desired frequency is reached. Allow approximately two minutes for the etalon temperature to fully stabilize.
2. Verify single-frequency performance using a scanning interferometer.
3. Temporarily engage ModeTrack to precisely align the etalon transmission curve with the desired longitudinal mode. Wait for the output power to be maximized (3 to 15 minutes). Skip this step if the absolute frequency of the laser is not important.
4. Engage ν-Track for active stabilization at this frequency. Note that at the initiation of ν-Track, the cavity length will be swept to maximize output power and align the longitudinal mode with the etalon transmission curve. If the desired absolute laser frequency is not achieved, make small adjustments to the etalon temperature and iterate steps 1 through 4.

The system will automatically switch to Manual mode whenever an error occurs while not in Manual operation mode.

The etalon optic will remain stabilized at the Manual temperature setting as long as the system keyswitch remains ON, even when the laser is deionized.

Setting to Manual Mode

To set the single-frequency mode to Manual without changing the etalon temperature or Z-axis DAC settings, navigate the menu tree as shown in Figures 8-8 or 8-9 to enter

the etalon temperature select sub-menu or the Z-axis DAC select sub-menu. It is not necessary to select a specific temperature or Z-axis DAC setting, the laser will switch to Manual as soon as the 'Manual Etalon Temp' or 'Manual Z Axis DAC' menu is selected.

Alternatively, the single-frequency mode can be set to Manual through external computer control (Command: Etalon Mode = 0).

Setting the Etalon Temperature

Manually setting the etalon temperature adjusts the position of the etalon transmission curve with respect to the laser gain curve (see Chapter Ten, Theory of Operation). To change the etalon temperature, navigate the menu tree as shown in Figure 8-8 to enter the etalon temperature select sub-menu. In this sub-menu, the etalon set temperature (°C) and error (°C) are displayed on the first line. The actual measured temperature equals the set temperature plus the error. A small error between the actual and set temperature is normal. Use the up/down arrows to scroll the value on the second line to the desired temperature setting and press SELECT to set that temperature. The set temperature can be adjusted in the range of 51.500 to 56.500 °C. The actual etalon temperature will respond and stabilize in a few minutes.

Alternatively, through external computer control, the set etalon temperature can be selected (Command: Etalon Temperature = nn.nnn) or read (Query: Print Set Etalon Temperature).

Setting the Z-Axis DAC Position

Manually setting the Z-axis DAC position adjusts the longitudinal mode positions with respect to the laser gain curve (see Chapter Ten, Theory of Operation).

To change the Z-axis DAC setpoint, navigate the menu tree as shown in Figure 8-9 to enter the Z-axis DAC select sub-menu. In this sub-menu, the Z-axis DAC setpoint is displayed on the first line. Use the up/down arrows to scroll the value on the second line to the desired setpoint and press SELECT to set that position. The Z-axis DAC may be adjusted within a maximum range of 300 to 3796. The valid limits of the Z-axis DAC range are dependent on the PowerTrack DAC values as discussed in a previous section. Higher Z-axis DAC values imply longer cavity lengths. The Z-axis DAC setting is automatically centered (2048) each time the laser is started or when the TUNE procedure is initiated.

Alternatively, through external computer control, the Z-axis DAC can be set (Command: ZDAC = n) or read (Query: Print ZDAC).

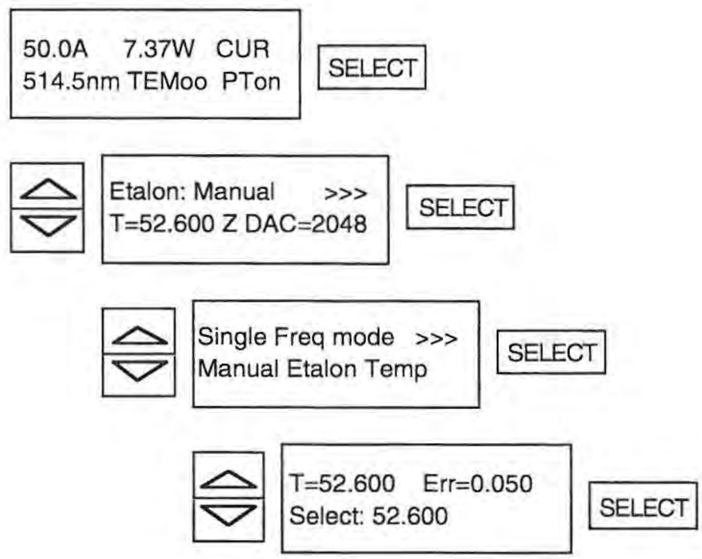


Figure 8-8. Manual Etalon Temperature Control Path

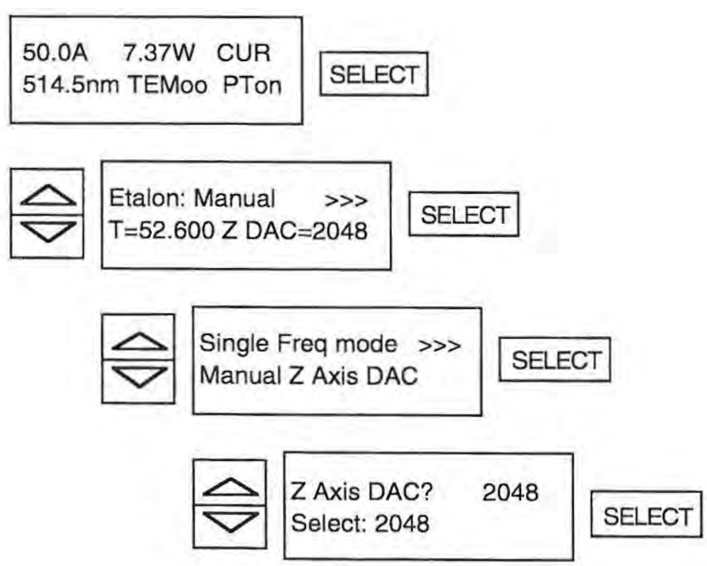


Figure 8-9. Manual Z-Axis DAC Control Path

ModeTune

ModeTune is an automatic tuning routine that fine tunes the etalon temperature and Z-axis DAC to achieve maximum single-frequency output power. For maximum power the etalon transmission curve must be aligned with the peak of the laser gain curve (Chapter Ten, Theory of Operation). ModeTune replaces the task of manually adjusting the etalon temperature and Z-axis DAC while monitoring output power and a spectrum analyzer.

When ModeTune is activated, it will automatically engage PowerTrack and switch the laser into Current Regulation Mode. It will slowly ramp the etalon set temperature in 0.03 °C increments, through its entire temperature range, while adjusting the Z-axis DAC and sampling the output power. When complete, it will set the temperature to the optimum value and automatically engage ModeFineTune (see below).

Single-Frequency Setup

For ModeTune to operate correctly, the laser must be properly setup and aligned for single-frequency operation as previously described in the Sabre Etalon Installation procedure. The aperture must be correctly set for single transverse mode TEM_{00} output. All head covers must be in place. When properly aligned, the output power will follow the above described sawtooth pattern during initial system warm-up when operated in Manual mode and Current Regulation.

For UV lines and high gain lines like 488.0 nm, ModeTune may not always select a single-frequency mode when tube current is above 55 A. For best results, it is recommended that the laser be on for at least 5 minutes (20 minutes if keyswitch was OFF), at a current of 55 A or less to run ModeTune.

The system must be lasing and the intracavity shutter must be in the OPEN position (Chapter Five, System Description and Control). When ModeTune is operating, do not adjust any controls which could affect the output power. When ModeTune is active, the following control functions will be disabled: current level changes, Light Regulation Mode, wavelength or rear motor changes, aperture changes, PowerTrack mode changes, and TUNE activation. ModeTune should be activated and then allowed to run until it and ModeFineTune are finished and ν-Track engages.

When to Use ModeTune

Use ModeTune whenever you want to temperature tune the etalon for peak single-frequency power. The resulting set temperature for peak power will usually change only if etalon or mirror alignment has changed significantly. Therefore, it may be sufficient to run ModeTune only when initially setting up in single-frequency. Record the resultant temperature setting. If the temperature is changed either manually or by significant drift while in ModeTrack, simply reset the temperature manually to the recorded peak setting (or run ModeTune) to return to maximum power.

For best results, it is recommended that the laser be on for at least 5 minutes at a current of 55 A or less before starting ModeTune. After ModeTune and ModeFineTune are complete (ν-Track active), the operating Current or Light Regulation level can be set as desired.

ModeTune can be used to reset the etalon temperature for maximum power if the temperature hits the end of its range during ModeTrack.

ModeTune cannot operate when the laser is off or if the etalon oven has not reached a temperature of 50 °C or greater. In either case a ModeTune error will occur.

How to Start ModeTune

To start ModeTune at any time (after the laser is on and the etalon warmed up), navigate the menu tree as shown in Figure 8-10 to enter the Single Freq mode select sub-menu. Use the up/down arrows to scroll to ModeTune and press SELECT. ModeTune will begin and "ModeTune" will be displayed on the first line of the "Etalon Menu" top level while ModeTune is running. ModeTune will also turn on PowerTrack and Current Regulation while running.

Alternatively, ModeTune can be activated through external computer control (Command: Etalon Mode = 2).

How to Stop ModeTune

After approximately 15 minutes ModeTune will set the etalon temperature and Z-axis DAC for peak power and engage ModeFineTune. "FineTune" will be displayed on the first line of the "Etalon Menu" top level.

ModeTune can also be aborted while running by setting the etalon to Manual mode (see above) or starting ModeFineTune, ν-Track or ModeTrack. In either case, the temperature setting will be whatever it was last when ModeTune was running unless changed manually.

ModeTune will abort with MTuneErr displayed if the laser in shut off or if the actual etalon temperature should fall below 50 °C due to an oven failure.

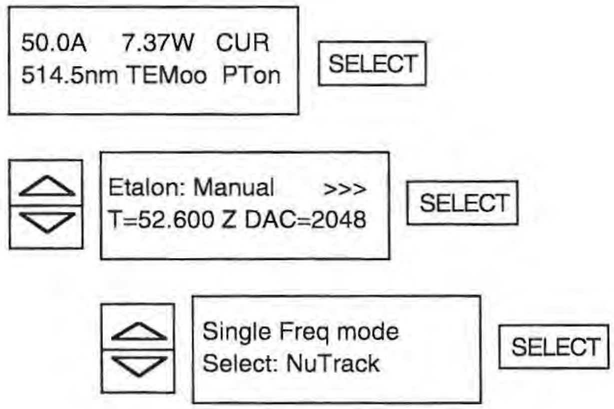


Figure 8-10. Single-Frequency Mode Control Path

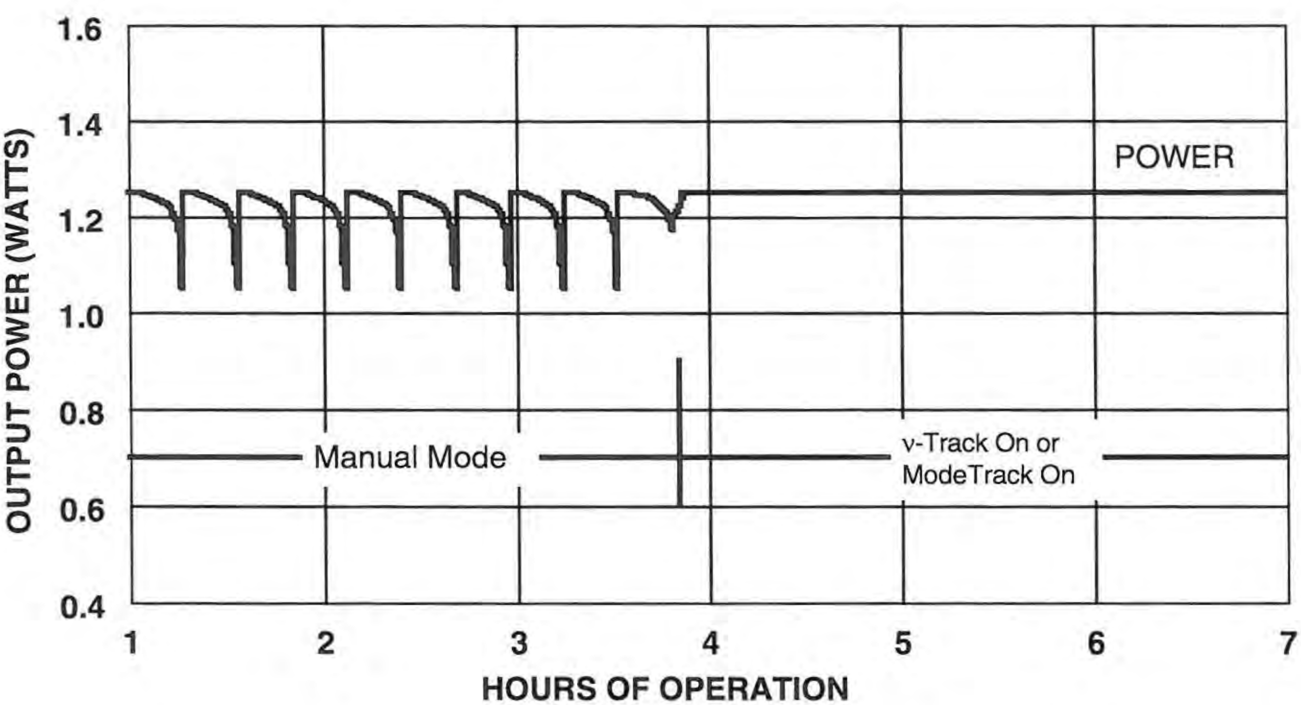


Figure 8-11. Typical ν-Track / ModeTrack Performance (Output power versus time)

ModeTune Errors

If a ModeTune error occurs, the etalon will switch to Manual mode and "MTuneErr" will be displayed on the first line of the "Etalon Menu" top level. The following conditions will be recognized by ModeTune as errors:

- Start ModeTune with laser off.
- Start ModeTune when actual etalon temperature is <50 °C.
- If actual temperature drops below 50 °C during operation.
- If laser is shut off during operation.

ModeFineTune

ModeFineTune is a ModeTune subroutine that precisely searches for and sets the etalon temperature and Z-axis DAC to achieve maximum single-frequency output power when the temperature is initially near the peak. While ModeFineTune is automatically incorporated into ModeTune, it can also be accessed separately. ModeFineTune can be used to ensure that single-frequency operation is at the closest nearby etalon temperature that produces a maximum output power. For maximum power the etalon transmission curve must be aligned with the peak of the laser gain curve (Chapter Ten, Theory of Operation).

When ModeFineTune is activated, it will automatically engage PowerTrack and switch the laser into Current Regulation Mode. It will slowly scan the etalon set temperature in 0.003 °C increments while adjusting the Z-axis DAC and sampling the output power to locate the peak. When complete, it will set the temperature to the optimum value and automatically engage ν-Track for active stabilization (see below).

Single-Frequency Setup

For ModeFineTune to operate correctly, the laser must be properly setup and aligned for single-frequency operation as previously described in the Sabre Etalon Installation procedure. The aperture must be correctly set for single transverse mode TEM_{00} output. All head covers must be in place. Course etalon temperature tuning must have already been performed after etalon installation and alignment using ModeTune.

The system must be lasing and the intracavity shutter must be in the OPEN position (Chapter Five, System Description and Control). When ModeFineTune is operating, do not adjust any controls which could affect the output power. When

ModeFineTune is active, the following control functions will be disabled: current level changes, Light Regulation Mode, wavelength or rear motor changes, aperture changes, PowerTrack mode changes, and TUNE activation. ModeFineTune should be activated and then allowed to run until it is finished and ν-Track engages.

When to Use ModeFineTune

Use ModeFineTune whenever you want to fine tune the etalon for peak single-frequency power after the initial installation and running of ModeTune. The resulting set temperature for peak power will usually change only slightly from day to day. Therefore, it may be sufficient to run ModeFineTune (as opposed to ModeTune) on a daily basis to assure peak output power. Record the resultant temperature setting. ModeFineTune can be used to reset the Z-axis DAC setpoint for maximum power if the setpoint hits the end of its range during ν-Track.

ModeFineTune cannot operate when the laser is off or if the etalon oven has not reached a temperature of 50 °C or greater. In either case a ModeFineTune error will occur. For best results, it is recommended that the laser be on for at least 5 minutes to run ModeFineTune.

How to Start ModeFineTune

To start ModeFineTune at any time (after the laser is on and the etalon warmed up), navigate the menu tree as shown in Figure 8-10 to enter the Single Freq mode select sub-menu. Use the up/down arrows to scroll to ModeFineTune and press SELECT. ModeFineTune will begin and "FineTune" will be displayed on the first line of the "Etalon Menu" top level while ModeFineTune is running. ModeFineTune will also turn on PowerTrack and Current Regulation while running.

Alternatively, ModeFineTune can be activated through external computer control (Command: Etalon Mode = 3).

How to Stop ModeFineTune

After approximately 5 minutes ModeFineTune will set the etalon temperature and Z-axis DAC for peak power and engage ν-Track. "NuTrack" will be displayed on the first line of the "Etalon Menu" top level.

ModeFineTune can also be aborted while running by setting the etalon to Manual mode (see above) or starting ModeTune, ν-Track or ModeTrack. In either case, the temperature setting

will be whatever it was last when ModeFineTune was running unless changed manually.

ModeFineTune will abort with "FTuneErr" displayed if the laser in shut off or if the actual etalon temperature should fall below 50 °C due to an oven failure.

ModeFineTune Errors

If a ModeFineTune error occurs, the etalon will switch to Manual mode and "FTuneErr" will be displayed on the first line of the "Etalon Menu" top level. The following conditions will be recognized by ModeFineTune as errors:

- Start ModeFineTune with laser off.
- Start ModeFineTune when actual etalon temperature < 50 °C.
- If actual temperature drops below 50 °C during operation.
- If laser is shut off during operation.

ν-Track

ν-Track is an active stabilization loop that continuously adjusts the Z-axis DAC to eliminate laser cavity length changes and prevent frequency drift (and thus also mode-hopping and power drift). When operated in Manual mode (etalon temperature fixed and Z-axis DAC), changes in resonator temperature will cause the frequency mode to drift with respect to the etalon transmission curve causing large power fluctuations and unpredictable mode hops. ν-Track adjusts the cavity length to maintain the alignment of the lasing longitudinal mode with the etalon transmission curve. (Chapter Ten, Theory of Operation). The frequency stability of the temperature dependent etalon transmission curve is excellent almost eliminating any frequency drift of the lasing mode. (See Chapter Two, System Specifications and Parameters for drift specification).

PowerTrack and Light Regulation Mode can be used in conjunction with ν-Track.

Single-Frequency Setup

For ν-Track to operate correctly the laser must be properly setup and aligned for single-frequency operation as previously described in the Sabre Etalon Installation procedure. The aperture must be correctly set for single transverse mode TEM_{00} output. All head covers must be in place. When properly aligned, the output power will follow the previously described sawtooth pattern during initial

system warm-up when operated in Manual mode and Current Regulation.

For reliable ν-Track operation, allow the laser to warm up 5 minutes in Manual mode and Current Regulation Mode before starting ν-Track.

Do not perform etalon alignment while ν-Track is operating. If it becomes necessary to mechanically align the etalon, select the Manual etalon mode before making adjustments, then run ModeTune as in the etalon alignment procedure above.

When to Use ν-Track

For long term single-frequency stability and mode-hop free operation, ν-Track is the recommended mode of operation. ν-Track locks the laser frequency to the etalon transmission curve. The resulting frequency stability of the laser is determined by the temperature stability of the etalon. (See Chapter Two, System Specifications and Parameters for drift specification).

Use ν-Track with PowerTrack and Light Regulation mode for optimum power stability, minimum noise and minimal frequency drift.

When the laser is first started, the heat of the laser tube and magnet will cause the head temperature to increase up to 12 °C. Approximately 8 °C of this change will occur during the first hour. For reliable ν-Track operation and maximum range, allow the laser to warm up 5 minutes in Manual mode and Current Regulation mode before starting ν-Track. Within the first 3 hours of system ionization, engagement of ν-Track will result in an initial Z-axis DAC setpoint that is approximately 3/4 of the available range above the lower limit to compensate for expected cavity length changes. After that time period, subsequent engagement of ν-Track will initially operate near the center of its available Z-axis DAC range.

ν-Track can typically handle long term temperature changes of +/-10° C before running out of range. In a typical installation it is expected that less than a quarter of the nominal range would be required. ν-Track can be used continuously after the initial laser warm-up.

ν-Track will not operate when the laser is off or if the etalon oven has not reached a temperature of 50 °C or greater. In either case, a ν-Track error will occur.

How to Start ν-Track

To start ν-Track at any time (after the laser is on and warmed up), navigate the menu tree as shown in Figure 8-10 to enter the Single Freq mode select sub-menu. Use the up/down arrows to scroll to NuTrack and press SELECT. ν-Track will begin and "NuTrack" will be displayed on the first line of the "Etalon Menu" top level while ν-Track is running.

ν-Track is automatically activated whenever ModeTune and ModeFineTune tuning routines are completed.

Alternatively, ν-Track can be activated through external computer control (Command: Etalon Mode = 4).

PowerTrack and Light Regulation with ν-Track

ν-Track is completely compatible with PowerTrack and Light Regulation. PowerTrack and Light Regulation can be toggled on or off using the PWR TRK and LIGHT buttons as usual once ν-Track is operating. When in Light Regulation Mode, reduce the power 5 to 10% from maximum to allow the system adequate room to adjust the current for changing light output. The interrelationship between Powertrack and the Z-axis DAC had been described in a previous section.

The laser current or power can be adjusted as usual even while ν-Track is operating (though not recommended). However, if the change is large, mode hops may occur during the first few minutes immediately following the adjustment.

How to Stop ν-Track

To stop ν-Track at any time during operation, navigate the menus as shown above to set to Manual mode. Or select ModeTune, ModeFineTune, or ModeTrack to stop ν-Track and start another function.

The system will automatically switch to Manual mode whenever TUNE is engaged, a new wavelength is requested, or if the laser is shut off.

ν-Track will switch to Manual mode and display "NTrackErr" if the Z-axis DAC setpoint reaches the ends of its operating range.

ν-Track Errors

If a ν-Track error occurs, the etalon will switch to Manual mode and "NTrackErr" will be displayed on the first line of the "Etalon Menu" top level. The following conditions will be recognized by ν-Track as errors:

- Start ν-Track with laser off.
- Start ν-Track when actual etalon temperature is < 50 °C.

- If actual temperature drops below 50 °C during operation.
- If the Z-axis DAC setpoint reaches the end of the available range during ν-Track operation; run ModeFineTune.

ModeTrack

ModeTrack is an active stabilization loop that continuously adjusts the etalon temperature to lock on to and track the drift of the lasing longitudinal mode and prevent mode hopping. When operated in Manual mode (etalon temperature fixed and Z-axis DAC), changes in resonator temperature will cause the frequency mode to drift with respect to the etalon transmission curve causing large power fluctuations and unpredictable mode hops. ModeTrack simply maintains the alignment of the etalon transmission curve with the lasing longitudinal mode (as it drifts with respect to the laser gain curve). It stabilizes output power and prevents mode hops. Frequency drift is directly determined by the amount of temperature change seen by the resonator (long-term change).

PowerTrack and Light Regulation Mode can be used in conjunction with ModeTrack.

Single-Frequency Setup

For ModeTrack to operate correctly the laser must be properly setup and aligned for single-frequency operation as previously described in the Sabre Etalon Installation procedure. The aperture must be correctly set for single transverse mode TEM_{00} output. All head covers must be in place. When properly aligned, the output power will follow the previously described sawtooth pattern during initial warm-up when operated in Manual mode and Current Regulation.

For reliable ModeTrack operation, allow the laser to warm up 5 minutes in Manual mode and Current Regulation before starting ModeTrack.

Due to the limited response time of the etalon oven, ModeTrack will only operate reliably for frequency drifts of about 500 MHz/hour or less (>9 minutes per mode hop). The drift of the Sabre SuperInvar resonator typically is less than 50 MHz/°C. Therefore, ModeTrack will reliably prevent mode hopping for long term ambient air or cooling water changes of about 5 °C/hour or less. For high drift rates near the limit of reliable ModeTrack operation, the output power will be less stable.

Do not perform etalon alignment while ModeTrack is operating. If it becomes necessary to mechanically align the etalon, select the Manual etalon mode before making adjustments, then run ModeTune as in the etalon alignment procedure above.

When to Use ModeTrack

ModeTrack may be used as an alternative to ν-Track, usually when the laser is fully warmed up and environmental temperature is stable. ModeTrack locks the etalon transmission curve to the longitudinal mode frequency. The resulting frequency stability of the laser depends on the length stability of the resonator (The drift of the Sabre SuperInvar resonator typically is less than 50 MHz/°C). For immediate and long term single-frequency stability and mode-hop free operation, ν-Track is the recommended mode of operation.

Use ModeTrack with PowerTrack and Light Regulation mode for optimum power stability and minimum noise.

When the laser is first started, the heat of the laser tube and magnet will cause the head temperature to increase up to 12 °C. Approximately 8 °C of this change will occur during the first hour. For reliable ModeTrack operation, allow the laser to warm up at least 5 minutes in Manual mode and Current Regulation before starting ModeTrack. ModeTrack can typically handle long term temperature changes of +/-15 °C before mode hopping. In a typical installation it is expected that less than a sixth of this range would be required. Increase the warm-up time to preserve more of the operating range for environmental temperature changes. ModeTrack can then be used continuously after the initial laser warm-up. If drift is large, occasionally the temperature must be reset to the starting temperature (or use ModeTune) to maximize power.

ModeTrack will not operate when the laser is off or if the etalon oven has not reached a temperature of 50 °C or greater. In either case, a ModeTrack error will occur.

How to Start ModeTrack

To start ModeTrack at any time (after the laser is on and warmed up), navigate the menu tree as shown in Figure 8-10 to enter the Single Freq mode select sub-menu. Use the up/down arrows to scroll to ModeTrack and press SELECT. ModeTrack will begin and "ModeTrack" will be displayed on the first line of the "Etalon Menu" top level while ModeTrack is running.

Alternatively, ModeTrack can be activated through external computer control (Command: Etalon Mode = 1).

After turning ModeTrack on, the frequency of the lasing mode may continue to drift, without mode hops, as the laser continues to warm-up. This drift will result in a gradual power decrease over the next hour or two. The power can be maximized at any time by running ModeTune or by manually resetting the etalon temperature to the initial value when ModeTrack was started (then restart ModeTrack).

PowerTrack and Light Regulation with ModeTrack

ModeTrack is completely compatible with PowerTrack and Light Regulation Mode. PowerTrack and Light Regulation can be toggled on or off using the PWR TRK and LIGHT buttons as usual once ModeTrack is operating. When in Light Regulation Mode, reduce the power 5 to 10% from maximum to allow the system adequate room to adjust the current for changing light output. The reduction necessary to prevent Light Regulation from going out of range will depend on the frequency drift rate.

The laser current or power can be adjusted as usual even while ModeTrack is operating (though not recommended). However, if the change is large, mode hops may occur during the first few minutes immediately following the adjustment. Large current changes will also increase the frequency drift.

How to Stop ModeTrack

To stop ModeTrack at any time during operation, navigate the menus as shown above to set to Manual mode. Or select ModeTune, ModeFineTune, or ν-Track to stop ModeTrack and start another function.

The system will automatically switch to Manual mode whenever TUNE is engaged, a new wavelength is requested, or if the laser is shut off.

ModeTrack will switch to Manual mode and display "MTrackErr" if the etalon temperature reaches the end of its operating range (51.500 °C or 56.500 °C).

ModeTrack Errors

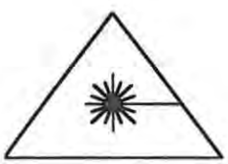
If a ModeTrack error occurs, the etalon will switch to Manual mode and "MTrackErr" will be displayed on the first line of the "Etalon Menu" top level. The following conditions will be recognized by ModeTrack as errors:

- Start ModeTrack with laser off.

- Start ModeTrack when actual etalon temperature is < 50 °C.
- If actual temperature drops below 50 °C during operation.
- If the set temperature reaches the end of the available range (51.500 °C or 56.500 °C) during ModeTrack operation; run ModeTune.

Single-Frequency Daily Operation

The following procedures are recommended for routine daily turn on and shut down of the laser when operating in single-frequency mode. It is assumed that the etalon has been properly installed, aligned and tuned for optimal power using the procedures above. Refer to Chapter Six, Daily Operation, for further information on daily operation procedures not specific to single-frequency operation.



Ensure that all personnel in the area are wearing laser safely glasses, or goggles, which protect against the wavelengths used, at all times during operation of the laser.

Turn Off

1. Press the ON/OFF button on the remote or use external control (Command: Laser = 0) to shut off the laser.
2. Allow the Sabre heat exchanger to run through its cool down period and shut off before proceeding to next step.
3. The power supply keyswitch should be left ON to maintain etalon temperature and reduce warm-up time at turn on. If so, press the SHUTTER button on the remote or use external control (Command: Shutter = 0) to close the external shutter. Otherwise, turn OFF the keyswitch and main facility power.

Turn On

1. Turn ON main facility power, if applicable.
2. Turn ON power supply keyswitch, if applicable.
3. If laser is set for Light Regulation Mode, change to Current Regulation by pressing the LIGHT button on the

remote or use external computer control (Command: Current = nn.nn).

4. Press the ON/OFF button on the remote or use external control (Command: Laser = 1) to turn on the laser. Wait for laser ionization.

5. Open the intracavity shutter if it is closed.

6. Allow 5 minutes for the laser to warm up (10 to 20 minutes if the keyswitch was left off).

7. Start ν-Track if the keyswitch had been ON or start ModeFineTune to fine peak the etalon temperature and automatically engage ν-Track if the keyswitch had been OFF. Wait until the single-frequency mode changes to ν-Track.

8. Set the laser to Light Regulation Mode, if desired, by pressing the LIGHT button on the remote or use external computer control (Command: Light = nn.nnnn).

9. When ready, press the SHUTTER button on the remote or use external control (Command: Shutter = 1) to open the external shutter.

Operator's Manual

Chapter Nine
Troubleshooting

COHERENT

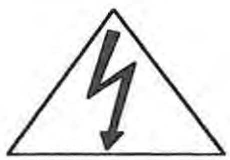
Introduction

This chapter contains preventive maintenance procedures, system warning messages, troubleshooting, and corrective procedures for specific problems.

Preventive Maintenance

Monthly inspection of water and electrical connections will help ensure that the laser system is in good operating condition.

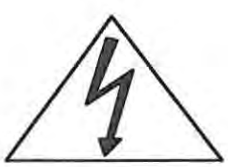
Water System Inspection



Circuits in the laser head operate at high voltages. HIGH VOLTAGES CAN BE LETHAL. Turn off laser before removing the laser head sub-covers. Do not operate the laser system with the covers removed.

Inspect water hoses, fittings, and connections for signs of wear, corrosion, or leaks. Water connections are located on the power supply rear panel, on the Sabre heat exchanger rear panel, and inside the laser head. In addition, inspect system connections to the facility water supply and drain lines. Repair water leaks and replace worn hoses immediately.

Electrical Inspection



Circuits in the laser head operate at high voltages. HIGH VOLTAGES CAN BE LETHAL. Turn off laser before removing the laser head sub-covers. Wait for the completion of the Sabre heat exchanger cool down time period and shut off main facility power. Do not operate the laser system with the covers removed.

Only qualified personnel should perform electrical repairs inside the power supply.

Inspect electrical connections to ensure good contacts. Also check that wiring and insulation are in good condition. Electrical connections are located inside the laser head. Take particular care when inspecting the anode and cathode leads as they carry high currents. Look for discoloration on the wire insulation, a sign that excessive heat is building up in the wire.

Also check for any loose, small objects (screws, for example) which may have fallen into the laser head. They may cause electrical failure or mechanical interference.

In addition, inspect the user supplied main facility power connector and AC hook-up for signs of overheating.

System Warning Messages

The remote control module will display two system warning messages as conditions warrant. "Autofill warning: 10 hours to shutdown" is displayed prior to an autofill automatic shutdown. "Warning: Resistivity low" is displayed when the inlet water resistivity drops into a low range. Order a replacement DI/DO cartridge and install. More information is available in Chapter Five, System Description and Control, in the respective sections titled: AUTOFILL: Automatic Shutdown and Sabre HEAT EXCHANGER: Monitoring Water Resistivity.

The system warning messages are not available through external computer control. The appropriate system operating parameters should be periodically monitored to anticipate the possibility of an impending shut down.

Using the Troubleshooting Section

The troubleshooting section is comprised of two parts: listings of possible problems with their accompanying explanations or remedies followed by troubleshooting flow charts and/or charts containing text that are referred to in the fault listings.

Table 9-1 contains a listing of possible system faults. System faults are conditions that may exist which make the laser inoperable or cause its performance to be not up to specification. Table 9-2 contains a listing of system fault messages displayed on the "Default Menu" level of the remote control module or accessible through external computer control (Query: Print Faults).

To use the troubleshooting section, find the system fault or fault message that best matches the problem encountered and read the accompanying explanation or remedy to clarify or correct the situation. The remedy may be a reference to a chart. If the chart is comprised only of text, follow the steps in the order presented. If the chart is comprised of a flow chart and text, follow the various paths of the flow chart in an attempt to resolve the problem. Some of the boxes in the flow chart may contain numbers in parentheses. These numbers refer to points listed in the text portion of the chart that explain in detail the procedures required by that step in the flow chart.

For some of the problems listed, the remedy or final step in a chart may require scheduling of a service call. A visit by Coherent Field Service may not always be necessary and some of the problems may be resolved over the phone by Coherent Technical Support. A description of the problem's symptoms and the steps taken in an attempt to resolve the problem will facilitate the planning of a course of action. The troubleshooting charts may also request the recording of system operating parameters which will be useful in determination of the probable source of the problem. If the system has a problem which cannot be repaired by the operator, then a service call by Coherent Field Service must be scheduled by calling 1-800-367-7890 within the United States, or 408-764-4557 outside of the United States.

Table 9-1. System Faults

System Fault	Explanation/Remedy
System does not power up.	Refer to Chart 1.
No display on remote control module.	Refer to Chart 2.
Tube does not ionize.	Refer to Chart 3.
System not lasing, but tube ionized.	Refer to Chart 4.
Low output power.	Refer to Chart 5.
Output power fluctuates.	Refer to Chart 6.
Specified wavelength not found.	Refer to Chart 7.

Table 9-2. System Fault Messages

Fault Message	Explanation/Remedy
Low Water Flow	Water flow rate of secondary cooling loop has dropped below 5.0 gallons (18.9 liters) per minute. Refer to Chart 8.
H/E Low Reservoir	Water level in Sabre heat exchanger is too low. Shut down facility power. Check connections of power cable between heat exchanger and power supply. Check water level in reservoir and correct as required.
Inlet Water Temp	Inlet temperature to power supply is not in the range of 10 to 35 °C (50 to 95 °F). Refer to Chart 9.
Line Phase Order	Incorrect order of the three phase facility main power. Have a qualified facilities technician swap any two phases, except the green ground wire, at user supplied main power connector.
External Interlock	Proper continuity of external interlock, located on the rear of the power supply, not maintained. Install factory supplied jumper to the two top terminals of the terminal strip or correct user supplied external interlock circuit.
Head Interlock	Proper continuity of the laser head interlocks, located on the front and rear bezels, not maintained. Check that the front and/or rear laser head sub-covers are properly seated.
Remote Interlock	Power supply has lost established communication with the remote control module for more than 10 seconds. Check connections at power supply and remote.
Interlock Fault	Momentary failure of head, external, or (internally disabled) power supply interlock. Check head and external interlocks. Schedule a service call.
PS Interlock	Fault is internally disabled. Reserved for a power supply cover interlock. Schedule a service call.
High Ripple I	Power supply's filter capacitor ripple current has exceed 15 Amps.
Low Fan Speed	Power supply's circulating fan is rotating too slowly. Schedule a service call.
Passbank Fault	Passbank transistor or internal interlock failure. Schedule a service call.
High Passbank I	Passbank (power supply) current has exceeded its maximum limit. Schedule a service call.
Contactor NOT ON	Power supply main contactor found to be disengaged when it was requested to be engaged. Schedule a service call.
Contactor NOT OFF	Power supply main contactor found to be engaged when it was requested to be disengaged. Schedule a service call.
Low Tube Voltage	A tube voltage of less than 200 Volts has been measured prior to firing of the starter. Schedule a service call.

Table 9-2. System Fault Messages

Fault Message	Explanation/Remedy
Low Starter Volt	Starter circuit voltage too low. Schedule a service call.
Fired Starter 5x	Starter has fired five times without ionizing the plasma tube. Schedule a service call.
Low Magnet I	Magnet current has dropped below 3 Amps. Schedule a service call.
High Magnet I	Magnet current has exceed 25 Amps. Schedule a service call.
High Magnet Temp	Temperature of magnet was found to be too high. Schedule a service call.
Low Cathode I	Cathode current has dropped below 20 Amps rms. Schedule a service call.
High Cathode I	Cathode current has exceeded 48 Amps rms. Schedule a service call.
Cathode Not Cal	Cathode requires calibration. Schedule a service call.
Cathode NOT OFF	Cathode was found to be on when it was set to be off. Schedule a service call.
Low Pressure	Tube pressure has produced an autofill delta less than -5 Volts if operating below the autofill threshold tube current of 20 Amps or has produced an autofill delta less than -7 Volts after giving three fills if operating above 20 Amps. Schedule a service call.
Low I Shutdown Start at 30 Amps	Operating conditions prevented the tube from taking a fill for 100 hours of operation with a negative autofill delta. Refer to Chapter Five, System Description and Control in the section titled: AUTOFILL: Automatic Shutdown.
Bad Autofill Cal	Magnitude of autofill delta indicates that the autofill curve, tube voltage, or tube current is uncalibrated. Schedule a service call.
Ready Valve Fault	Autofill ready valve failure. Schedule a service call.
Fill Valve Fault	Autofill fill valve failure. Schedule a service call.
Over Temperature	Temperature of water temperature exiting the power supply was found to be too high. Schedule a service call.
Remote Communication	Power supply buffer overflow. Schedule a service call.
Head Comm Error	Power supply unable to communicate properly with the head. Schedule a service call.
Head Req Shutoff	Head has requested shutdown for a fault not supported by power supply software version or specific fault data was lost. Schedule a service call.
PS EEPROM Fault	Error detected in power supply calibration EEPROM. Schedule a service call.

Table 9-2. System Fault Messages

Fault Message	Explanation/Remedy
Tube EEPROM Fault	Error detected in plasma tube calibration EEPROM. Schedule a service call.
Head EEPROM Fault	Error detected in laser head calibration EEPROM. Schedule a service call.
Head/PS Mismatch	Improper match of maximum current of power supply and laser head. Schedule a service call.

Chart 1. System Fault: System Does Not Power Up

This procedure assumes that the keyswitch is ON, remote display is blank, indicator LEDs on front of power supply are off, and external computer control is unresponsive.

Check the following items:

[1] All water, power, and electrical connections are secure:

- Facility to system power and water connections.
- Laser head to power supply umbilical connection.
- Sabre heat exchanger to power supply power and water connections.
- Remote control module to power supply connections.

[2] Primary loop facility cooling water input and drain are turned on.

[3] Primary and secondary heat exchanger water flow directions are correct.

[4] Power supply main fuse block is closed (located on power supply rear panel).

[5] Facility main power circuit breaker is turned on.

[6] User-supplied main power connector is correctly wired. Disconnect laser system from facility power before checking wiring. Refer to Chapter Four, Utility Requirements and System Installation.

[7] All three incoming power phases are present. Consult a qualified electrician to perform this check.

[8] Check main line fuse (3) as follows:

Before attempting to check fuses, all power must be removed.

Three 80 Amps fuses are located in the main fuse block on the rear panel of the power supply. Refer to Figure 5-8.

- Turn off keyswitch. Turn the facility main power circuit breaker off. Disconnect the power cable from the facility power.
- Open the main fuse block. Use a multimeter to measure the resistance of the fuses. A good fuse will have approximately zero resistance.
- If a bad fuse is found, a serious problem may exist in the power supply. Catastrophic damage may result if the fuse is replaced without advice from Coherent Technical Support.

[9] Schedule a service call.

Chart 2. System Fault: No Display on Remote Control Module

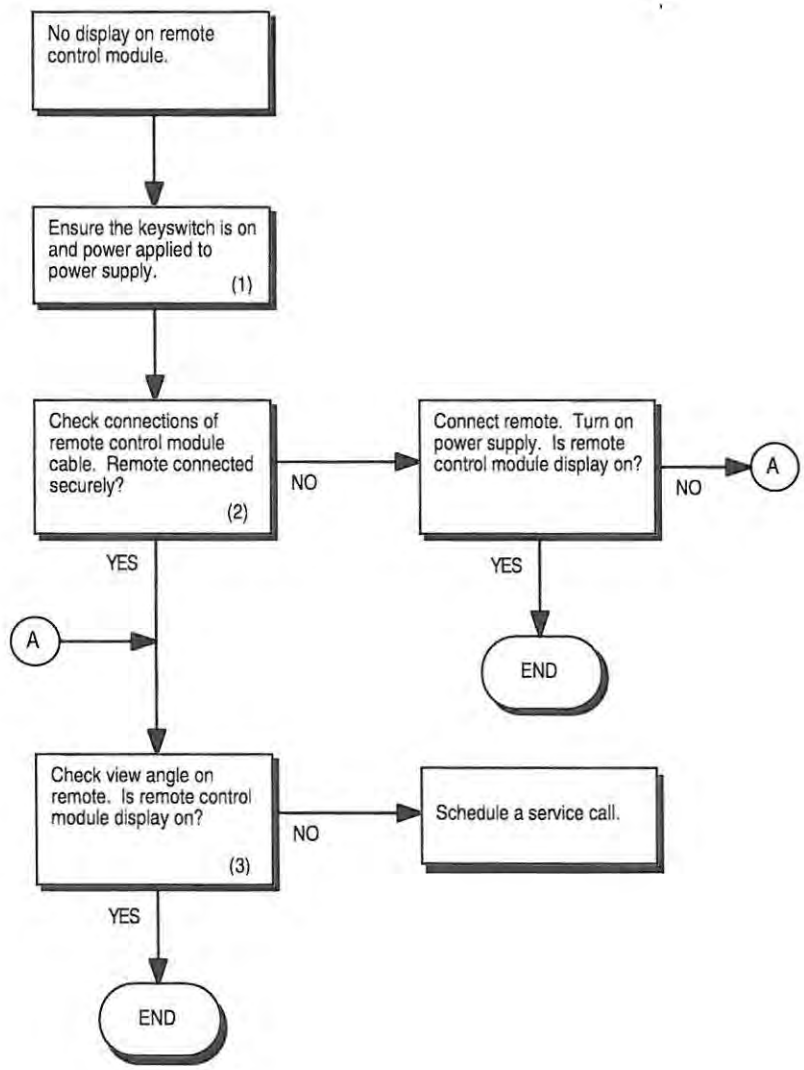


Chart 2. System Fault: No Display on Remote Control Module

(Cont'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[1] If both of the power supply indicator LEDs are on, power is applied to the power supply. Refer to Chart 1 if the system does not power up.

[2] Turn off keyswitch. Attach cable if necessary. If cable connections appear OK, unplug and re-attach the cable connections at the remote control module and power supply to ensure proper connection. Turn on keyswitch.

[3] On the rear of the remote control module is a small access hole labeled "VIEW ANGLE". A small insulated straight blade screwdriver, such as a pot tweaker, may be inserted and the small white screw potentiometer inside may be rotated approximately one full turn.

Chart 3. System Fault: Tube Does Not Ionize

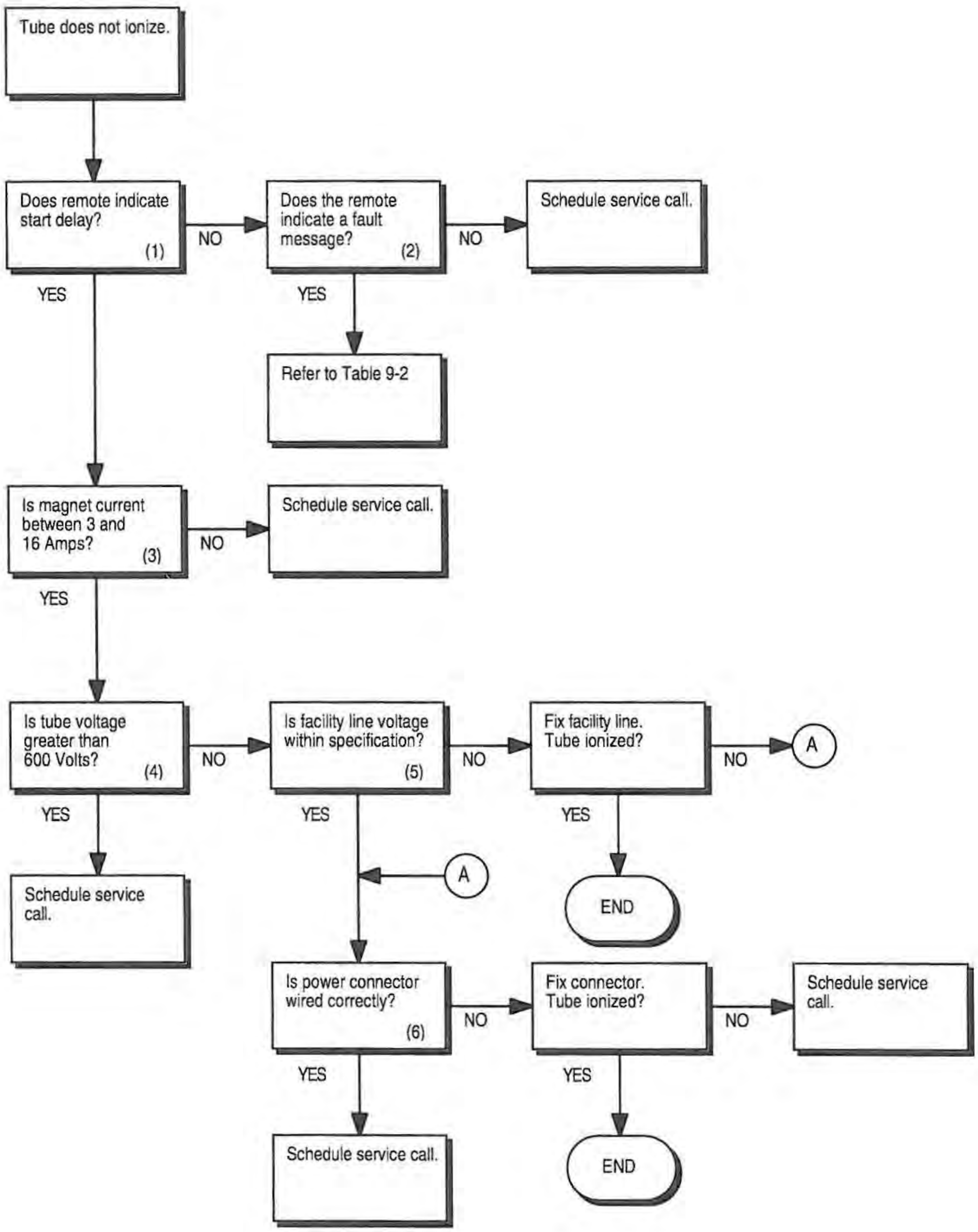


Chart 3. System Fault: Tube Does Not Ionize (Cont'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[1] Verify that remote displays "Start Delay":

- Cycle the keyswitch OFF then ON to ensure that "Default Menu" level is displayed on the remote.
- Press the ON button. Top line of remote display should indicate "Start Delay: 75" with the countdown time decrementing.
- After approximately 75 seconds, the countdown time should reach zero seconds.

[2] Navigate the remote display to the "Default Menu" level, if necessary, by pressing the Exit button repeatedly. Any system fault message will be displayed on the top line.

[3] Verify the magnet current as follows:

- From the "Default Menu" press the Select button.
- Use the up/down arrows to display the "Status Menu" and enter the associated lower level by pressing Select.
- Use the up/down arrows to scroll to the display indicating the cathode and magnet currents.
- Verify that the magnet current displayed is between 3 and 16 Amps. The typical value for argon Sabre is ~14 A, for krypton Sabre in low field is ~4.5 A, for krypton Sabre in high field is ~8 A.

[4] Verify the tube voltage as follows:

- From the "Default Menu" press the Select button.
- Use the up/down arrows to display the "Status Menu" and enter the associated lower level by pressing Select.
- Use the up/down arrows to scroll to the display indicating the Tube parameters: Power (P), Current (I), and Voltage (V).
- A tube voltage of >600 Volts should be displayed.

[5] Refer to Chapter Four, Utility Requirements and System Installation, for details concerning electrical service specifications.

Facility line must meet specifications with system operating at full current. Consult a qualified electrician to perform this check.

A step-up transformer may solve a line voltage problem. However, consult an electrician to determine whether or not this solution will fix your problem.

[6] Ensure that electrical power connector is correctly wired as described in Chapter Four, Utility Requirements and System Installation.

Chart 4. System Fault: System Not Lasing, But Tube Ionized

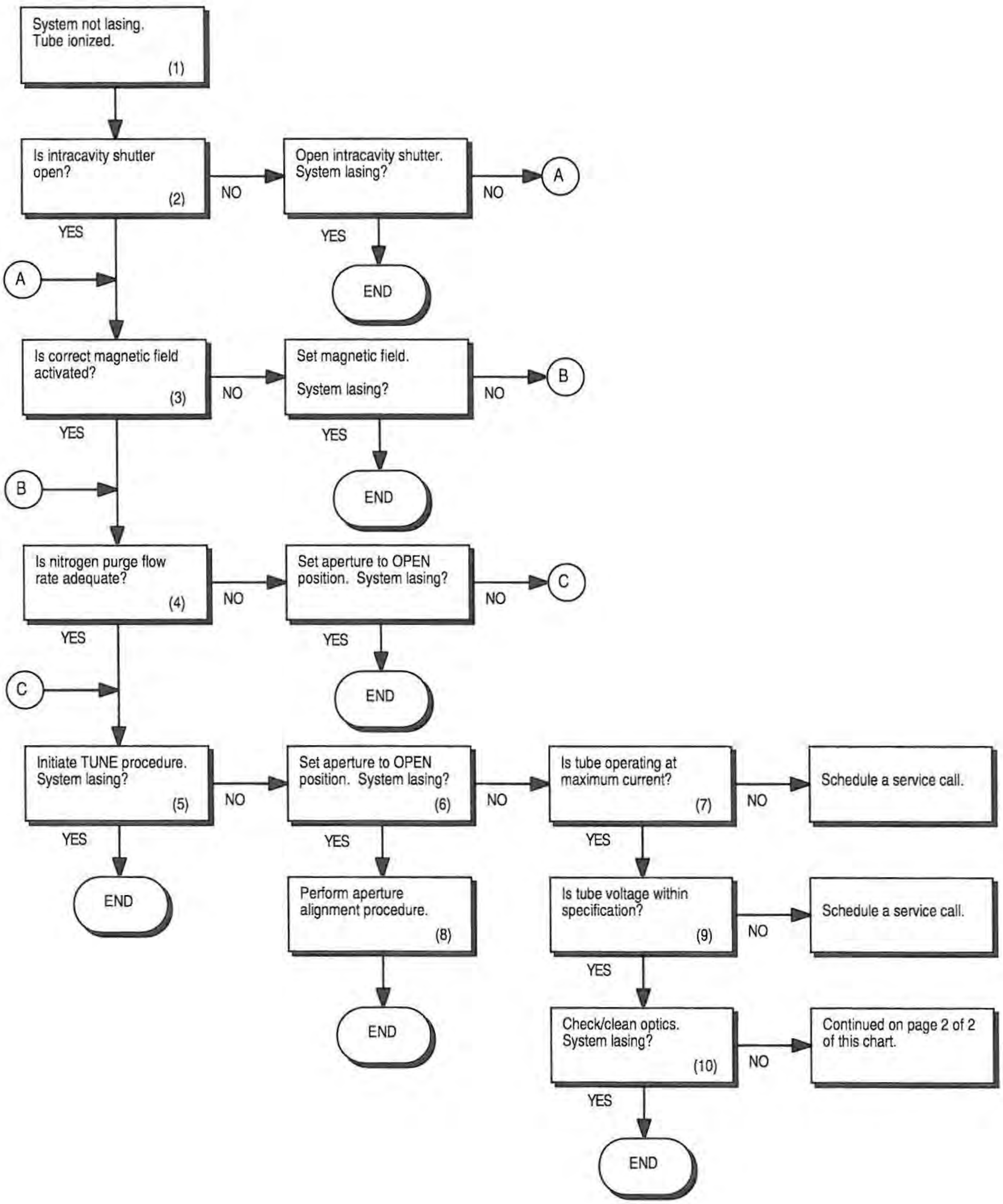


Chart 4.System Fault: System Not Lasing, But Tube Ionized (Cont'd)

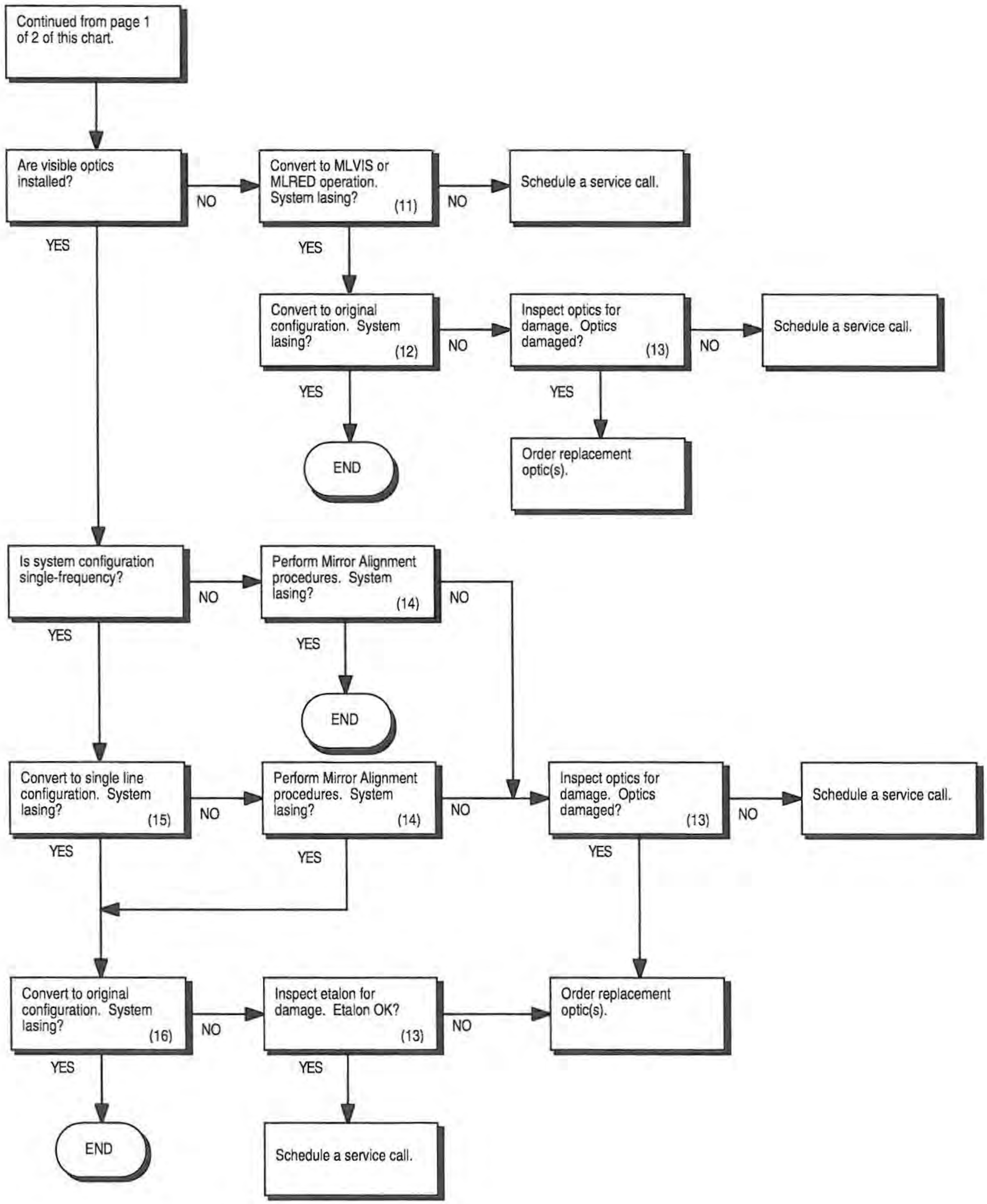


Chart 4. System Fault: System Not Lasing, But Tube Ionized (Cnt'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[1] Verify that the tube is ionized as follows:

a. Place a white card or piece of paper at the output end of the laser head. Open the external shutter by pressing the SHUTTER button such that the LED above it is off. A purplish glow should be visible on the white card. If necessary, turn off the room lights to facilitate observation.

b. If the purplish glow does not appear, the plasma tube may not be ionized. Refer to Chart 3.

[2] The intracavity shutter control is located near the rear of the laser head, as shown in Figure 5-11.

[3] On krypton Sabres only, the magnetic field has two settings. High field should be used for violet and UV wavelengths (≤ 468.0 nm). Low field should be used for all other wavelengths. On argon Sabres, the magnetic field setting is irrelevant.

Verify and/or set the correct magnetic field as follows:

a. From the "Default Menu" press the SELECT button.

b. Use the up/down arrows to display the upper level of the "Magnet Menu".

c. The value shown on the second line indicates the current magnetic field as sensed by the power supply hardware.

d. The magnetic field can only be changed when the system is off through the associated lower level of the "Magnet Menu". Press SELECT to enter the lower menu level.

e. The second line of the lower menu level indicates the set field. Use the up/down arrows to display the desired "Low field" or "High field" value and press SELECT.

[4] Only argon Sabre systems equipped with the deep or short UV options require nitrogen purges. The recommended flow rate, as indicated by the flowmeter supplied with the purge kit, is 1.0 ± 0.5 SCFH. The flow of nitrogen should be established well in advance of system ionization to remove any atmospheric oxygen from the intracavity space.

To check the purge paths in the laser head, shut the system down, wait for completion of the heat exchanger cool down period and shut down main facility power. Remove the front and rear head subcovers and ensure that all purge lines and connections are secure including: the output coupler bayonet mount, the aperture, and the rear of the laser head at the location shown in Figure 5-10.

[5] Initiate the TUNE procedure from the "Default Menu" by pressing the TUNE button. For more information, refer to Chapter Five, System Description and Control, in the section titled: LASER HEAD AND AUTOMATED FEATURES: Motorized Rear Mirror Plate: TUNE Procedure.

Chart 4. System Fault: System Not Lasing, But Tube Ionized (Cnt'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[6] Even if the "Default Menu" indicates that the current aperture position is OPEN, reasserting a request for the OPEN aperture position will ensure that it is set properly. Request the OPEN aperture position as follows:

a. From the "Default Menu" press the Select button.

b. Use the up/down arrows to display the "Aperture Menu" and enter the associated lowest level by pressing Select twice.

c. Use the up/down arrows to scroll to the parameter to the OPEN position. Press Select to initiate the aperture change or search.

d. Verify that the current aperture position displayed in the "Aperture Menu" is OPEN and that an aperture error has not occurred. If an aperture error, besides "Position reset", occurs then schedule a service call.

[7] The following will ensure that the system is capable of operating at maximum current.

a. Verify that the system is operating in Current Regulation Mode by observing the upper right corner of the remote "Default Menu" and the LED above the LIGHT button. The "Default Menu" should display "CUR" and the LED should be off. If "LT" or "LT–" is displayed on the "Default Menu", press the LIGHT button such that "CUR" is displayed. If the LED is flashing and "CUR" is displayed, press the down arrow until the LED is off.

b. Press the up arrow until the maximum current setting is displayed. If the maximum current setting is already displayed, verify functionality by pressing the down arrow and observing a decrease in the setting. Press up arrow to scroll back up to the maximum current setting. Note that the current displayed is the set current, not the measured or actual current value.

c. From the "Default Menu" press the Select button.

d. Use the up/down arrows to display the "Status Menu" and enter the associated lower level by pressing Select.

e. Use the up/down arrows to scroll to the display indicating the Tube parameters: Power (P), Current (I), and Voltage (V).

f. The measured or actual current value displayed should be within 0.5 Amps of the maximum current setting. If the current cannot be set correctly, schedule a service call.

[8] If the initial aperture position was not OPEN, then the aperture requires alignment. Refer to Chapter Seven, Optics and Alignment Procedures, in the section titled: APERTURE ALIGNMENT PROCEDURE. If, subsequently, the system lases at the OPEN aperture position only, then schedule a service call.

Chart 4. System Fault: System Not Lasing, But Tube Ionized (Cnt'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[9] Check the tube voltage as follows:

a. From the "Default Menu" press the Select button.

b. Use the up/down arrows to display the "Status Menu" and enter the associated lower level by pressing Select.

c. Use the up/down arrows to scroll to the display indicating the Tube parameters: Power (P), Current (I), and Voltage (V).

d. Verify that the tube voltage is within -2.0 to +25.0 Volts of specification as shown in Table 2-13. If the tube voltage is not in this range, record this value and schedule a service call.

[10] Ensure that the proper high reflector and output coupler for the requested wavelength are actually installed in the laser head. Check the orientation of each. (The arrow on each optic points towards the intracavity space.) As required, clean high reflector, single line prism (if installed), Brewster window(s), output coupler (if two-windowed system), and etalon (if installed) in accordance with the cleaning procedures described in Chapter Seven, Optics and Alignment Procedures, in the section and related sub-sections titled: CARE AND CLEANING OF OPTICS.

[11] To convert the system to multiline visible (or multiline red for krypton), refer to Chapter Seven, Optics and Alignment Procedures, in the section titled: CHANGING OPTIC SETS. As required, perform the Output Coupler Retroreflection Procedure, described in Chapter Seven, Optics and Alignment Procedures. Request MLVIS (or MLRED for krypton) from the "Wavelength Menu" to establish lasing, as described in Chapter Five, System Description and Control. Use the Walk-In Procedure to optimize alignment as described in Chapter Seven, Optics and Alignment Procedures.

If the system is sealed mirror UV, then the following generic procedure will be advised by Coherent Technical Support in conjunction with procedures described in the subsequent section titled: "MANUAL" CONTROL OF SYSTEM MOTORS: Motorized Rear Mirror Plate.

a. Install the multiline holder with a visible high reflector into the system.

b. Use "manual" control of the rear mirror plate to set the rear mirror plate to the known multiline cal position.

c. Establish a retroreflection from the high reflector, through the output coupler, and out of the front of the head. Use "manual" control of the horizontal and vertical rear mirror plate motors, if necessary, to align for retroreflection.

d. Install UV high reflector into multiline holder.

e. Perform the Vertical Search Procedure using the front mirror plate, as described in Chapter Seven, Optics and Alignment Procedures, to establish lasing. To optimize alignment, perform the Walk-In Procedure described in the same chapter. If lasing cannot be established, schedule a service call.

Chart 4. System Fault: System Not Lasing, But Tube Ionized (Cnt'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[12] To convert the system from multiline visible (or multiline red for krypton) to the original configuration, use the intermediate step of establishing multiline operation with the appropriate optic set. Refer to Chapter Seven, Optics and Alignment Procedures, in the section titled: CHANGING OPTIC SETS. Then, if applicable, convert from multiline to single line configuration, by referring to the same chapter in the section titled: MULTILINE/SINGLE LINE SWAP. Procedures for converting to the single-frequency configuration are described in Chapter Eight, Single-Frequency Operation.

[13] For optic inspection procedures, refer to Chapter Seven, Optics and Alignment Procedures, in the section titled: CARE AND CLEANING OF OPTICS: Optics Inspection.

[14] Perform the Output Coupler Retroreflection Procedure, described in Chapter Seven, Optics and Alignment Procedures. Initiate the TUNE procedure from the "Default Menu" by pressing the TUNE button to establish lasing, as described in Chapter Five, System Description and Control. Use the Walk-In Procedure to optimize alignment as described in Chapter Seven, Optics and Alignment Procedures. If the TUNE Procedure fails to establish lasing in the single line cavity configuration, convert to the mulitline cavity configuration and request the appropriate multiline wavelength from the "Wavelength Menu" to establish lasing.

[15] Remove the etalon oven and install the dummy etalon transition tube. Refer to Chapter Eight, Single-Frequency Operation, for details concerning these parts.

[16] Convert from multiline to single line configuration by referring to Chapter Seven, Optics and Alignment Procedures, in the section titled: MULTILINE/SINGLE LINE SWAP. Procedures for converting to the single-frequency configuration are described in Chapter Eight, Single-Frequency Operation.

Chart 5. System Fault: Low Output Power

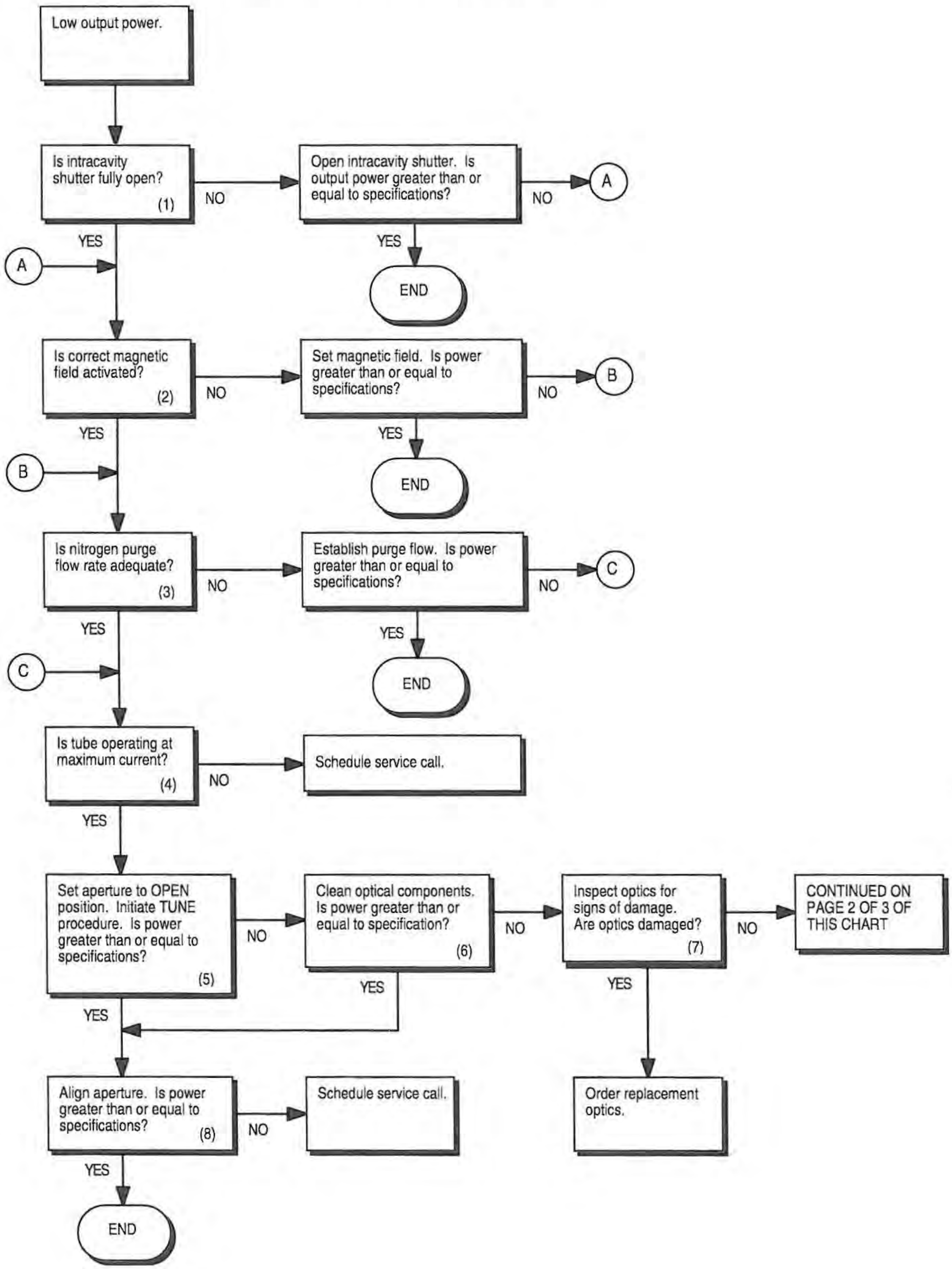


Chart 5. System Fault: Low Output Power (Cont'd)

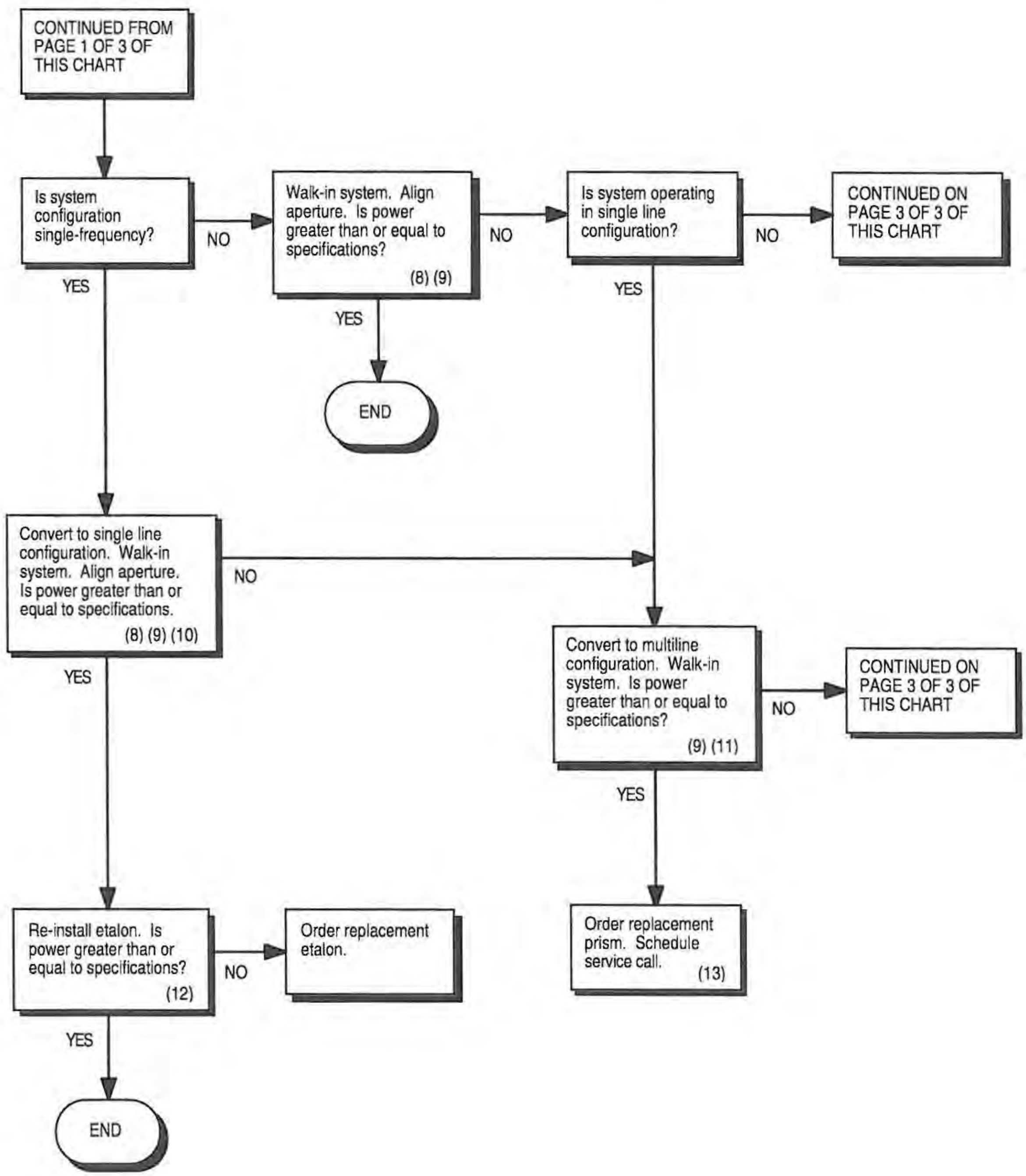


Chart 5. System Fault: Low Output Power (Cont'd)

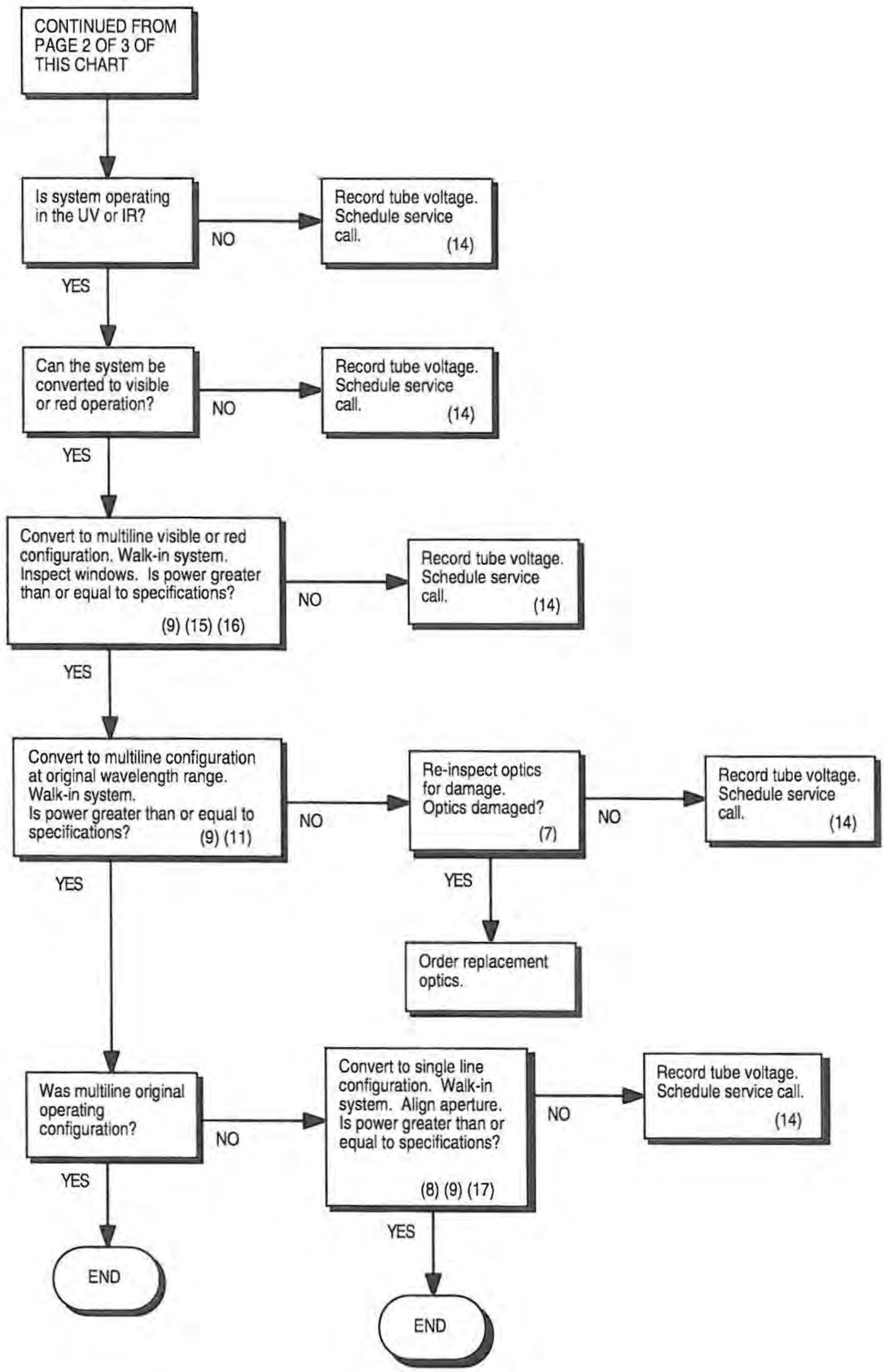


Chart 5. System Fault: Low Output Power (Cont'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[1] The intracavity shutter control is located near the rear of the laser head, as shown in Figure 5-11.

[2] On krypton Sabres only, the magnetic field has two settings. High field should be used for violet and UV wavelengths (≤ 468.0 nm). Low field should be used for all other wavelengths. On argon Sabres, the magnetic field setting is irrelevant.

Verify and/or set the correct magnetic field as follows:

a. From the "Default Menu" press the SELECT button.

b. Use the up/down arrows to display the upper level of the "Magnet Menu".

c. The value shown on the second line indicates the current magnetic field as sensed by the power supply hardware.

d. The magnetic field can only be changed when the system is off through the associated lower level of the "Magnet Menu". Press SELECT to enter the lower menu level.

e. The second line of the lower menu level indicates the set field. Use the up/down arrows to display the desired "Low field" or "High field" value and press SELECT.

[3] Only argon Sabre systems equipped with the deep or short UV options require nitrogen purges. The recommended flow rate, as indicated by the flowmeter supplied with the purge kit, is 1.0 ± 0.5 SCFH. The flow of nitrogen should be established well in advance of system ionization to remove any atmospheric oxygen from the intracavity space.

To check the purge paths in the laser head, shut the system down, wait for completion of the heat exchanger cool down period and shut down main facility power. Remove the front and rear head subcovers and ensure that all purge lines and connections are secure including: the output coupler bayonet mount, the aperture, and the rear of the laser head at the location shown in Figure 5-10.

[4] The following will ensure that the system is capable of operating at maximum current.

a. Verify that the system is operating in Current Regulation Mode by observing the upper right corner of the remote "Default Menu" and the LED above the LIGHT button. The "Default Menu" should display "CUR" and the LED should be off. If "LT" or "LT–" is displayed on the "Default Menu", press the LIGHT button such that "CUR" is displayed. If the LED is flashing and "CUR" is displayed, press the down arrow until the LED is off.

b. Press the up arrow until the maximum current setting is displayed. If the maximum current setting is already displayed, verify functionality by pressing the down arrow and observing a decrease in the setting. Press up arrow to scroll back up to the maximum current setting. Note that the current displayed is the set current, not the measured or actual current value.

c. From the "Default Menu" press the Select button.

d. Use the up/down arrows to display the "Status Menu" and enter the associated lower level by pressing Select.

e. Use the up/down arrows to scroll to the display indicating the Tube parameters: Power (P), Current (I), and Voltage (V).

f. The measured or actual current value displayed should be within 0.5 Amps of the maximum current setting. If the current cannot be set correctly, schedule a service call.

Chart 5. System Fault: Low Output Power (Cont'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[5] Even if the "Default Menu" indicates that the current aperture position is OPEN, re-asserting a request for the OPEN aperture position will ensure that it is set properly. Request the OPEN aperture position as follows:

a. From the "Default Menu" press the Select button.

b. Use the up/down arrows to display the "Aperture Menu" and enter the associated lowest level by pressing Select twice.

c. Use the up/down arrows to scroll to the OPEN position. Press Select to initiate the aperture change or search.

d. Verify that the current aperture position displayed in the "Aperture Menu" is OPEN and that an aperture error has not occurred. If an aperture error, besides "Position reset", occurs then schedule a service call.

Initiate the TUNE procedure from the "Default Menu" by pressing the TUNE button. For more information, refer to Chapter Five, System Description and Control, in the section titled: LASER HEAD AND AUTOMATED FEATURES: Motorized Rear Mirror Plate: TUNE Procedure.

[6] Ensure that the proper high reflector and output coupler for the requested wavelength are actually installed in the laser head. Check the orientation of each. (The arrow on each optic points towards the intracavity space.) As required, clean high reflector, single line prism (if installed), Brewster window(s), output coupler (if two-windowed system), and etalon (if installed) in accordance with the cleaning procedures described in Chapter Seven, Optics and Alignment Procedures, in the section and related sub-sections titled, CARE AND CLEANING OF OPTICs.

[7] For optic inspection procedures, refer to Chapter Seven, Optics and Alignment Procedures, in the subsection titled, CARE AND CLEANING OF OPTICS: Optics Inspection.

[8] If the initial aperture position was not OPEN, then the aperture requires alignment. Otherwise, to check and/or correct alignment, refer to Chapter Seven, Optics and Alignment Procedures, in the section titled, APERTURE ALIGNMENT PROCEDURE.

[9] Instructions for performing the Walk-In Procedure are located in Chapter Seven, Optics and Alignment Procedures.

[10] Remove the etalon oven and install the dummy etalon transition tube. Refer to Chapter Eight, Single-Frequency Operation, for details concerning these parts.

Chart 5. System Fault: Low Output Power (Cont'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[11] Convert between multiline and single line configurations by referring to Chapter Seven, Optics and Alignment Procedures, in the section titled, MULTILINE/SINGLE LINE SWAP.

[12] Procedures for converting to the single-frequency configuration are described in Chapter Eight, Single-Frequency Operation.

[13] Proper installation and alignment of a new prism must be performed by a qualified service technician.

[14] Check the tube voltage as follows:

a. From the "Default Menu" press the Select button.

b. Use the up/down arrows to display the "Status Menu" and enter the associated lower level by pressing Select.

c. Use the up/down arrows to scroll to the display indicating the Tube parameters: Power (P), Current (I), and Voltage (V).

d. Record the tube voltage value and schedule a service call.

[15] To convert the system configuration to multiline visible (or multiline red for krypton), refer to Chapter Seven, Optics and Alignment Procedures, in the section titled: CHANGING OPTIC SETS.

[16] Any Brewster window contamination, e.g. a speck of dust of a film that reflects light, will be easier to see when operating in the visible rather than the UV or IR. If found, attempt to re-clean the Brewster window(s) using the procedures described in Chapter Seven, Optics and Alignment Procedures in the section and related titled: CARE AND CLEANING OF OPTICS: Brewster Window. NOTE: Use extreme care in cleaning the window(s) to avoid scratching the surfaces.

[17] To convert the system from multiline to single line configuration, refer to Chapter Seven, Optics and Alignment Procedures, in the section titled: MULTILINE/SINGLE LINE SWAP.

Chart 6. System Fault: Output Power Fluctuates

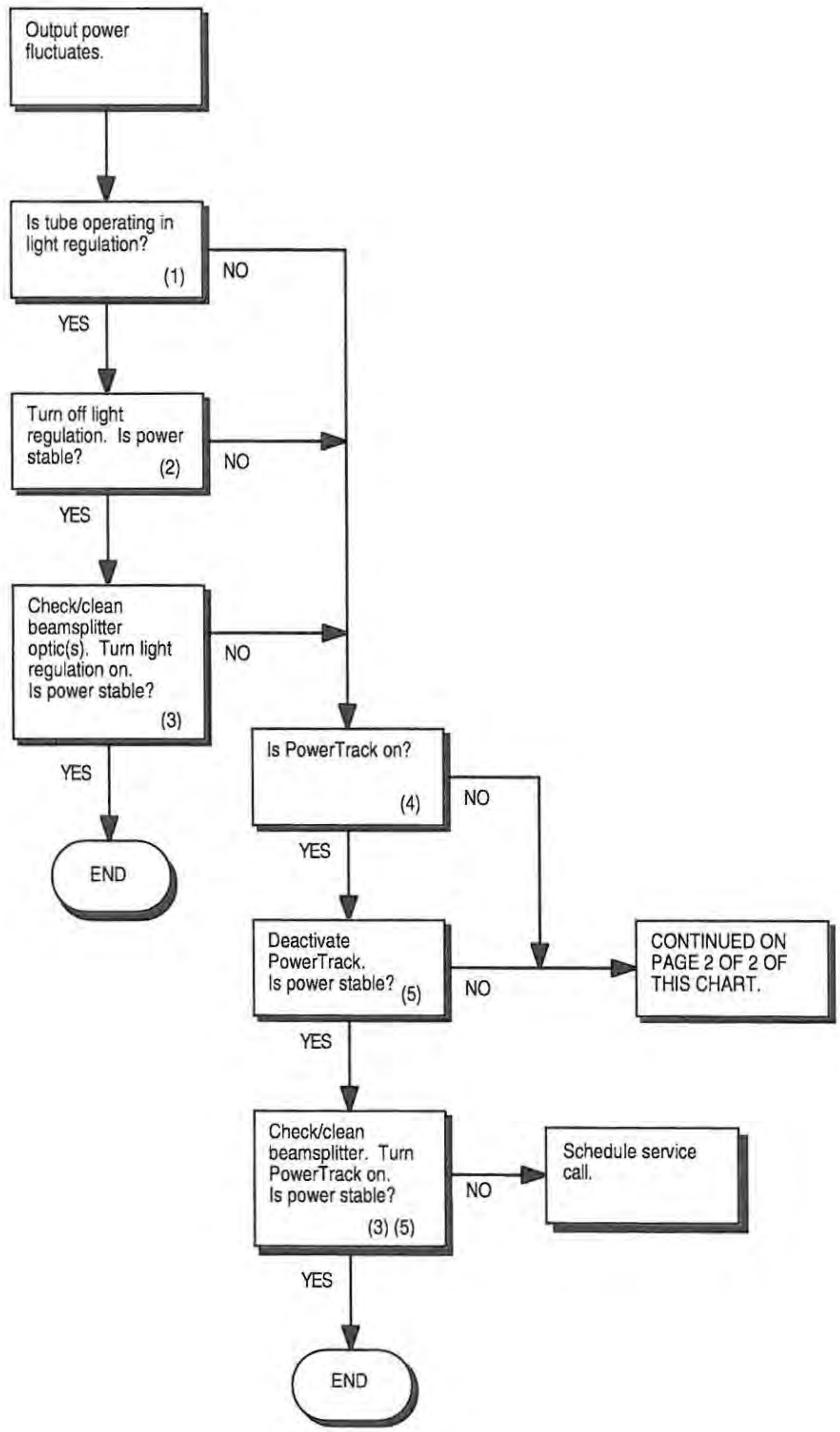


Chart 6. System Fault: Output Power Fluctuates (Cont'd)

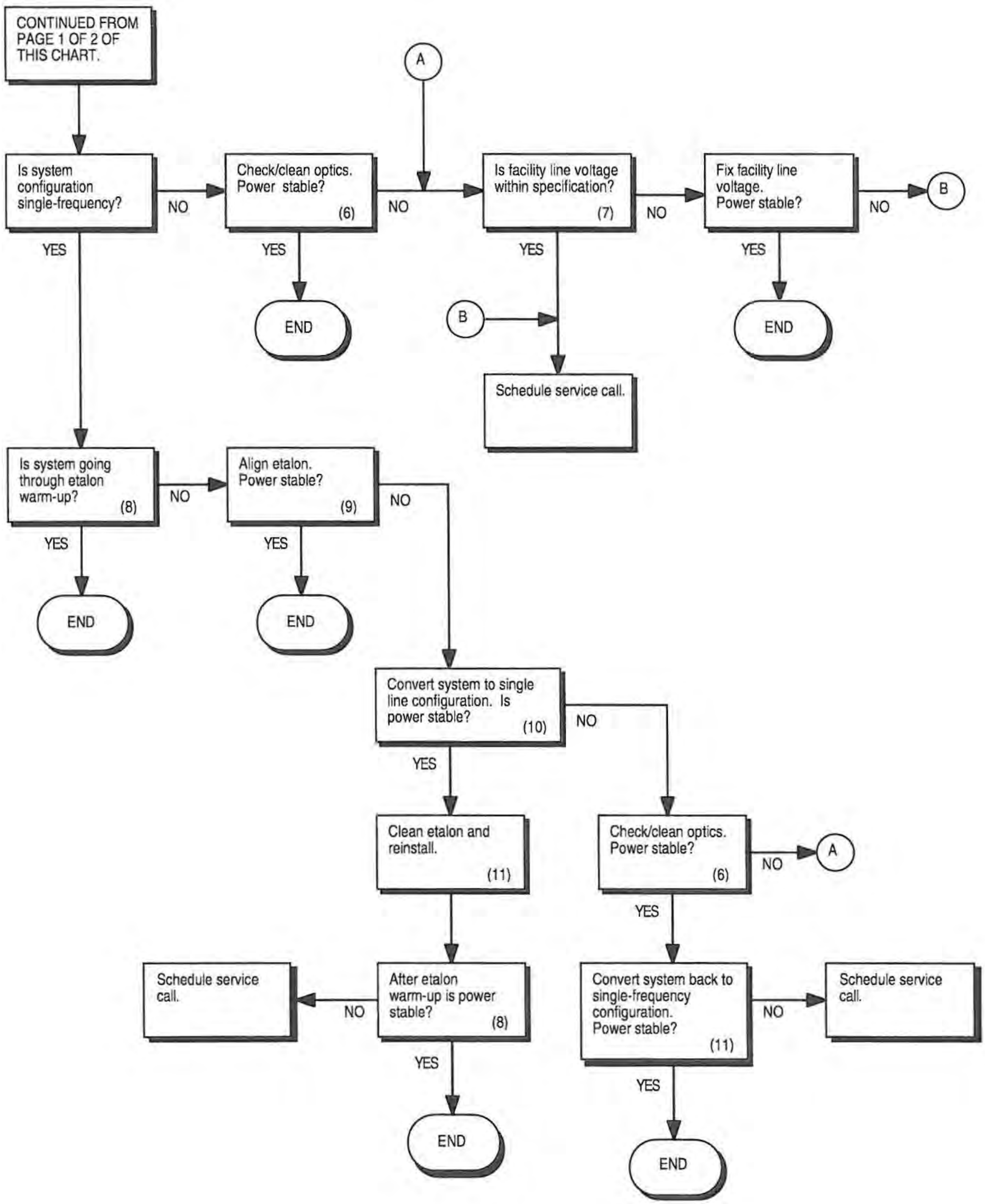


Chart 6. System Fault: Output Power Fluctuates (Cont'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[1] Determine the system regulation mode by observing the upper right corner of the remote "Default Menu" and the LED above the LIGHT button. The "Default Menu" will display "CUR" and the LED will be off if operating in Current Regulation Mode. The "Default Menu" will display "LT" or "LT–" and the LED will be steadily on if operating in Light Regulation Mode. If the LED is flashing and "CUR" is displayed, then Light Regulation is out of range. More information about the different regulation modes can be found in Chapter Five, System Description and Control.

[2] Turn Light Regulation Mode off as follows:

- If "LT" or "LT–" is displayed on the "Default Menu", press the LIGHT button such that "CUR" is displayed and the LED above the button is off.
- If the LED above the LIGHT button is flashing and "CUR" is displayed on the "Default Menu", press the down arrow until the LED is off.

Turn Light Regulation Mode on as follows:

- Press the LIGHT button such the "LT" or "LT–" is displayed on the "Default Menu" and the LED above the button is steadily on. If the LED is flashing, Light Regulation is out of range.

More information about the different regulation modes and the out of range condition can be found in Chapter Five, System Description and Control.

[3] Remove the beamsplitter assembly from its mounting block and inspect the cleanliness of the optics using the procedures described in Chapter Seven, Optics and Alignment Procedures in the sections titled: CARE AND CLEANING OF OPTICS: Beamsplitters and Optics Inspection. Clean the optics, if necessary, using procedures found in that chapter in the sub-section titled: Beamsplitter Cleaning. Check the beamsplitter alignment and correct if necessary using the procedures described in that chapter in the section titled: BEAMSPLITTER MOUNTING BLOCK ALIGNMENT.

[4] To determine the status of PowerTrack, observe the lower right corner of the "Default Menu" and the LED above the PWR TRK button on the remote. If PowerTrack is on and operational, "PT On" will be displayed and the LED will be continuously illuminated. If PowerTrack is off, "PT Off" will be displayed and the LED will be off. If "PT On" is displayed and the LED is off or flashing, then PowerTrack is parked or out of range. For more information, refer to Chapter Five, System Description and Control in the section titled: POWERTRACK: Acquisition of PowerTrack Status.

[5] To deactivate PowerTrack, press the PWR TRK button until the LED above it is off and the "Default Menu" displays "PT Off". To activate PowerTrack, press the PWR TRK button until the LED above it is steadily on and the "Default Menu" displays "PT On". For more information, refer to Chapter Five, System Description and Control in the section titled: POWERTRACK: Activation of PowerTrack.

Chart 6. System Fault: Output Power Fluctuates (Cont'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[6] For optic inspection procedures, refer to Chapter Seven, Optics and Alignment Procedures, in the section titled: CARE AND CLEANING OF OPTICS: Optics Inspection. As required, clean high reflector, single line prism (if installed), Brewster window(s), output coupler (if two-windowed system), and etalon (if installed) in accordance with the cleaning procedures described in Chapter Seven, Optics and Alignment Procedures in the section and related sub-sections titled: CARE AND CLEANING OF OPTICS.

[7] Refer to Chapter Four, Utility Requirements and System Installation, for details concerning electrical service specifications.

Facility line must meet specifications with system operating at full current. Consult a qualified electrician to perform this check.

[8] The etalon, when installed into its oven, will remain thermally stabilized as long as power is applied to the system and the keyswitch is ON. If this is not the case, operate in Current Regulation Mode and allow 20 minutes for etalon stabilization. If the keyswitch had been left ON, stable single-frequency performance should be attainable 5 to 10 minutes after system ionization though engagement of NuTrack. Refer to Chapter Eight, Single-Frequency Operation for more information.

[9] Procedures for etalon alignment are located in Chapter Eight, Single-Frequency Operation.

[10] Remove the etalon oven and install the dummy etalon transition tube. Refer to Chapter Eight, Single-Frequency Operation, for details concerning these parts.

[11] Procedures for converting to the single-frequency configuration are described in Chapter Eight, Single-Frequency Operation.

Chart 7. System Fault: Specified Wavelength Not Found

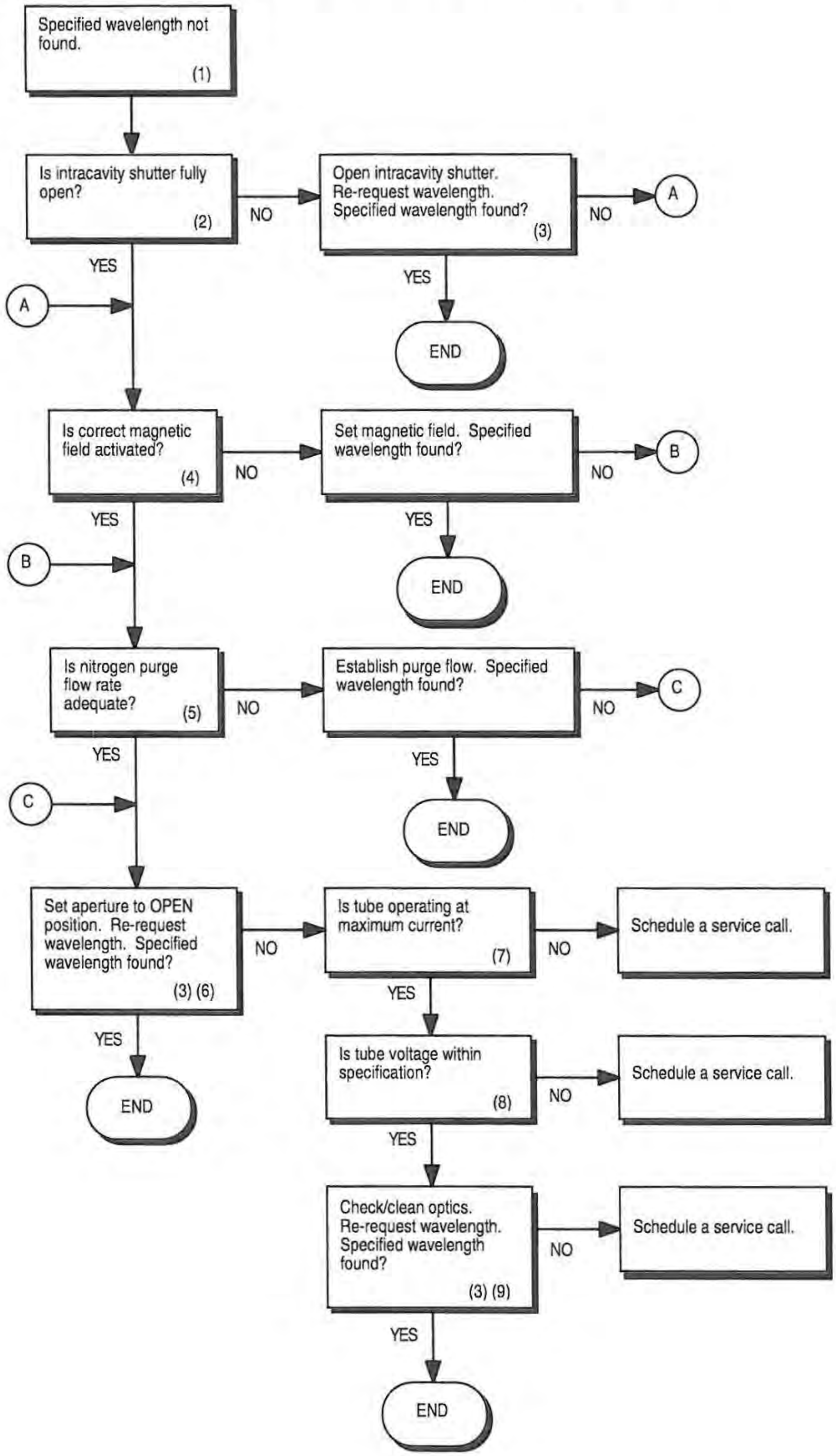


Chart 7. System Fault: Specified Wavelength Not Found (Cont'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[1] If the wavelength specified by the user is not found, the system will make a best guess of the wavelength of the line found. The second line of the "Wavelength Menu" will display "457.9nm found first", where, for example, 457.9nm is the wavelength of the best guess. External computer control will return the value "1" to the query "Print Wavelength Errors".

[2] The intracavity shutter control is located near the rear of the laser head, as shown in Figure 5-11.

[3] To re-request the specified wavelength, proceed as follows:

a. From the "Default Menu" press the Select button.

b. Use the up/down arrows to display the "Wavelength Menu" and enter the associated lower level by pressing Select.

c. Use the up/down arrows to scroll to the appropriate wavelength range and single line holder for the currently installed optic set. Press Select to enter the associated lower level.

d. Use the up/down arrows to scroll to the desired wavelength. Press Select to initiate the wavelength change.

[4] On krypton Sabres only, the magnetic field has two settings. High field should be used for violet and UV wavelengths (≤ 468.0 nm). Low field should be used for all other wavelengths. On argon Sabres, the magnetic field setting is irrelevant.

Verify and/or set the correct magnetic field as follows:

a. From the "Default Menu" press the SELECT button.

b. Use the up/down arrows to display the upper level of the "Magnet Menu".

c. The value shown on the second line indicates the current magnetic field as sensed by the power supply hardware.

d. The magnetic field can only be changed when the system is off through the associated lower level of the "Magnet Menu". Press SELECT to enter the lower menu level.

e. The second line of the lower menu level indicates the set field. Use the up/down arrows to display the desired "Low field" or "High field" value and press SELECT.

[5] Only argon Sabre systems equipped with the deep or short UV options require nitrogen purges. The recommended flow rate, as indicated by the flowmeter supplied with the purge kit, is 1.0 ± 0.5 SCFH. The flow of nitrogen should be established well in advance of system ionization to remove any atmospheric oxygen from the intracavity space.

To check the purge paths in the laser head, shut the system down, wait for completion of the heat exchanger cool down period and shut down main facility power. Remove the front and rear head subcovers and ensure that all purge lines and connections are secure including: the output coupler bayonet mount, the aperture, and the rear of the laser head at the location shown in Figure 5-10.

Chart 7. System Fault: Specified Wavelength Not Found (Cont'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[6] Even if the "Default Menu" indicates that the current aperture position is OPEN, re-asserting a request for the OPEN aperture position will ensure that it is set properly. Request the OPEN aperture position as follows:

a. From the "Default Menu" press the Select button.

b. Use the up/down arrows to display the "Aperture Menu" and enter the associated lowest level by pressing Select twice.

c. Use the up/down arrows to scroll to the OPEN position. Press Select to initiate the aperture change or search.

d. Verify that the current aperture position displayed in the "Aperture Menu" is OPEN and that an aperture error has not occurred. If an aperture error, besides "Position reset", occurs then schedule a service call.

[7] The following will ensure that the system is capable of operating at maximum current.

a. Verify that the system is operating in Current Regulation Mode by observing the upper right corner of the remote "Default Menu" and the LED above the LIGHT button. The "Default Menu" should display "CUR" and the LED should be off. If "LT" or "LT–" is displayed on the "Default Menu", press the LIGHT button such that "CUR" is displayed. If the LED is flashing and "CUR" is displayed, press the down arrow until the LED is off.

b. Press the up arrow until the maximum current setting is displayed. If the maximum current setting is already displayed, verify functionality by pressing the down arrow and observing a decrease in the setting. Press up arrow to scroll back up to the maximum current setting. Note that the current displayed is the set current, not the measured or actual current value.

c. From the "Default Menu" press the Select button.

d. Use the up/down arrows to display the "Status Menu" and enter the associated lower level by pressing Select.

e. Use the up/down arrows to scroll to the display indicating the Tube parameters: Power (P), Current (I), and Voltage (V).

f. The measured or actual current value displayed should be within 0.5 Amps of the maximum current setting. If the current cannot be set correctly, schedule a service call.

[8] Check the tube voltage as follows:

a. From the "Default Menu" press the Select button.

b. Use the up/down arrows to display the "Status Menu" and enter the associated lower level by pressing Select.

c. Use the up/down arrows to scroll to the display indicating the Tube parameters: Power (P), Current (I), and Voltage (V).

d. Verify that the tube voltage is within -2.0 to +25.0 Volts of specification as shown in Table 2-13. If the tube voltage is not in this range, record this value and schedule a service call.

Chart 7. System Fault: Specified Wavelength Not Found (Cont'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[9] Ensure that the proper high reflector and output coupler for the requested wavelength are actually installed in the laser head. Check the orientation of each. (The arrow on each optic points towards the intracavity space.) As required, clean high reflector, single line prism (if installed), Brewster window(s), output coupler (if two-windowed system), and etalon (if installed) in accordance with the cleaning procedures described in Chapter Seven, Optics and Alignment Procedures in the section and related sub-sections titled: CARE AND CLEANING OF OPTICS.

Chart 8. System Fault Message: Low Water Flow

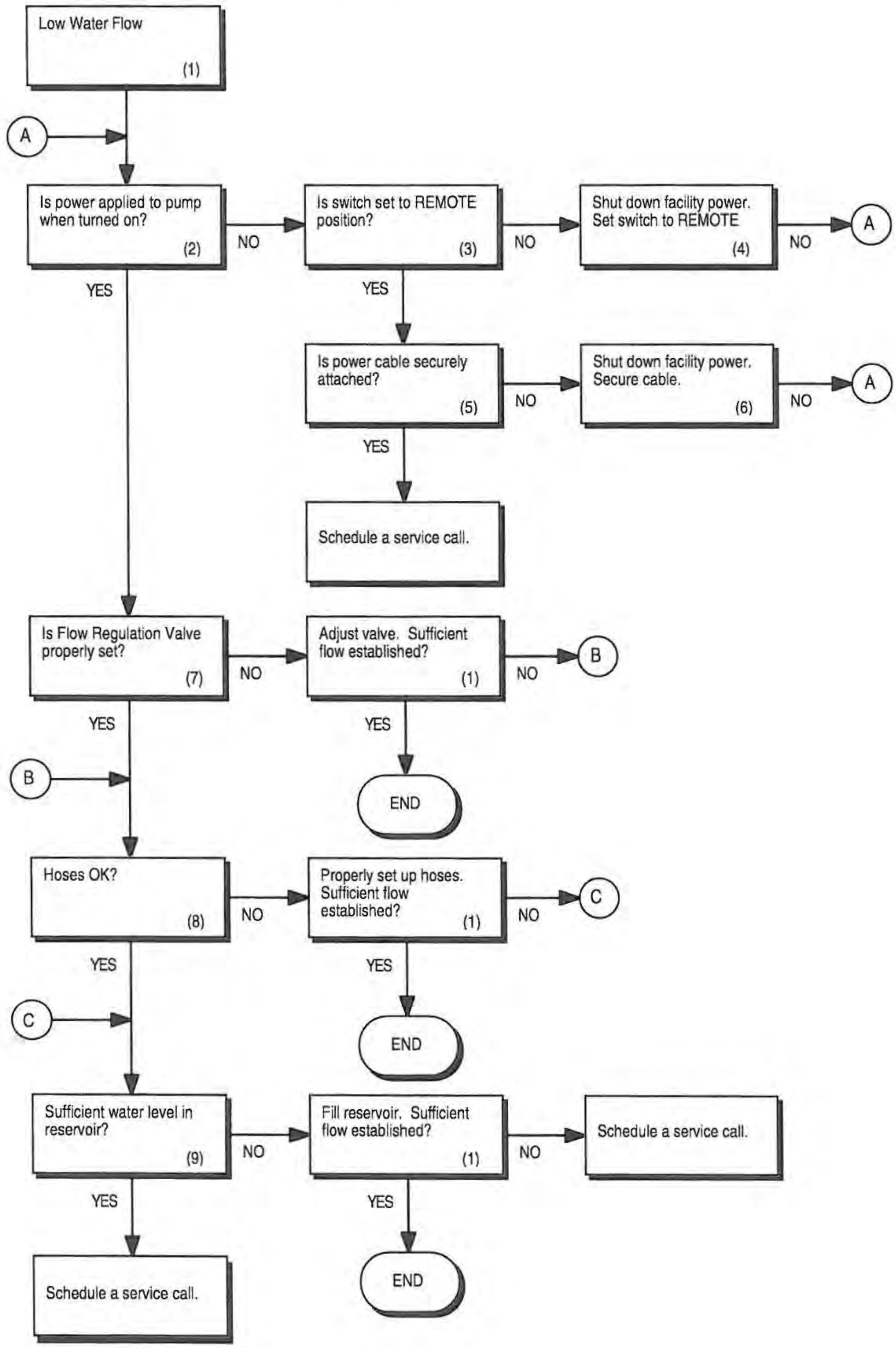


Chart 8. System Fault Message: Low Water Flow (Cont'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[1] Monitor the water flow rate reading from the remote control module as follows:

a. From the "Default Menu" press the Select button.

b. Use the up/down arrows to display the "Status Menu" and enter the associated lower level by pressing Select.

c. Use the up/down arrows to scroll to the display indicating the "Water Flow" rate in gallons per minute.

d. Sufficient water flow rate will be in the range of 6.0 to 8.0 gallons per minute (22.7 to 30.3 liters per minute). A recommended nominal value of flow rate is 6 gallons per minute.

For more information, refer to Chapter Five, System Description and Control, in the section titled: SABRE HEAT EXCHANGER: Controlling/Monitoring Flow Rate.

[2] Turn on the pump using manual heat exchanger control as follows:

a. From the "Default Menu" press the Select button.

b. Use the up/down arrows to display the "Diagnostics Menu" and enter the associated lower level by pressing Select.

c. Use the up/down arrows to display the "Diagnostics: Analog Menu" and enter the associated lower level by pressing Select.

d. Use the up/down arrows to scroll to the display the "Heat Exchanger Menu" and enter the associated lower level by pressing Select.

e. Use the up/down arrows to scroll to the "ON" parameter and press Select to apply power to the heat exchanger pump.

For more information, refer to Chapter Five, System Description and Control, in the section titled: SABRE HEAT EXCHANGER: Manual Heat Exchanger Control.

[3] The REMOTE/OFF switch is located on the front of the Sabre heat exchanger as shown in Figure 5-4.

[4] Shut down main facility power before setting the switch to the REMOTE position. This precautionary step will ensure that the pump does not engage unexpectedly when the switch on the heat exchanger is set to the REMOTE position. Re-establish main power after setting the switch to the REMOTE position.

[5] Visually inspect the heat exchanger power cable connections at the rear of the power supply and the rear of the heat exchanger, as shown in Figures 5-4 and 5-9. High voltage may present in the cable and/or at the connectors. To physically ensure proper connections, follow the procedures outlined in step 6.

Chart 8. System Fault Message: Low Water Flow (Cont'd)

The numbered paragraphs below are keyed to, and supplement the flowchart for this chart.

[6] Shut down main facility power. Disconnect and re-attach the heat exchanger power cable from its connectors at the rear of the power supply and the rear of the heat exchanger, as shown in Figure 5-4 and 5-9. Re-establish main facility power when done.

[7] The Flow Regulation Valve is located on the rear of the Sabre heat exchanger (refer to Figure 5-4). The valve may be rotated 1/4 of a turn. When the orientation of handle is horizontal, the valve will be fully open. When the orientation of the handle is vertical, the valve will be closed. A recommended nominal value flow rate of 6 gallons (22.7 liters) per minute positions the valve in an intermediary position.

[8] Check the hoses between the heat exchanger and the power supply for kinks or crushed sections due to heavy equipment. Ensure that the routing of the hoses labeled at their connections on the power supply as To/From Heat Exchanger are properly mated with the connections labeled on the heat exchanger as From/To Laser Power Supply. Refer to Chapter Four, Utility Requirements and System Installation, in the section titled: Connecting The Heat Exchanger.

[9] Ensure that the water level in the heat exchanger reservoir is adequate by examining it through the slit provided on the side of the heat exchanger main cover. If it is required to add water to the reservoir, shut down main facility power. Remove the small sub-cover on the top of the heat exchanger main cover. Unscrew the plastic cap of the reservoir and add additional water.

Chart 9. System Fault Message: Inlet Water Temp

[1] The temperature of the water input to the power supply can be controlled using the Temperature Regulation Valve located on the rear of the Sabre heat exchanger (refer to Figure 5-4). Rotation of the valve in a clockwise direction will result in cooler water temperature for the secondary closed loop entering the power supply.

Monitor the inlet water temperature reading from the remote control module as follows:

a. From the "Default Menu" press the Select button.

b. Use the up/down arrows to display the "Status Menu" and enter the associated lower level by pressing Select.

c. Use the up/down arrows to scroll to the display indicating the "Inlet Temp".

d. Ensure that the inlet temperature is between 20 and 35 °C (68 and 95 °F). A recommended nominal temperature is 30 °C when the system is ionized and fully warmed up.

[2] Check the temperature of the facility cooling water. The maximum temperature allowed is 30 °C (86 °F). Refer to Chapter Four, Utility Requirements and System Installation, in the section titled: UTILITY REQUIREMENTS: Cooling Water.

[3] Ensure that the water level in the heat exchanger reservoir is adequate by examining it through the slit provided on the side of the heat exchanger main cover. If it is required to add water to the reservoir, shut down main facility power. Remove the small sub-cover on the top of the heat exchanger main cover. Unscrew the plastic cap of the reservoir and add additional water.

[4] If all of the three conditions above are within specification and the system keeps shutting down with this fault, schedule a service call.

Manual Control of System Motors

In general, the software routines integrated into the system should be used to control the motorized rear mirror plate and the automatic aperture. Use of the automatic routines will maintain system calibration and will ensure proper system performance. Certain troubleshooting procedures may require the user to exercise "manual" control of the stepper motors incorporated into these automatic features. Note that manual control of system motors may corrupt calibration and inhibit proper system performance.

Motorized Rear Mirror Plate

The "manual" control of the motorized rear mirror plate allows the user to orientate the rear mirror plate to specific calibrated positions, perform a localized search procedure, and move the individual vertical and/or horizontal stepper motors a designated number of steps.

To access the lower level menus, enabling "manual" control of the motorized rear mirror plate, requires that the extended menus be displayed on the remote (Sabre Power Supply DIP switch 8 on MY TALK ADDRESS = ON). Navigate the menu tree to the "Diagnostics: Rear Mirror Menu" and access the desired path in the lower level menu tree shown in Figure 9-1.

Note that "manual" control of the rear mirror plate excludes many of the features of the built-in automatic routines and requires the user to set appropriate system operating conditions. PowerTrack should be turned Off and centered in its range. [To center PowerTrack, shut down the system and cycle the keyswitch OFF then ON or use external computer control (Command: PowerTrack = 3).] It is recommended to operate the system at maximum current with an OPEN aperture position. Ensure that the intracavity shutter is OPEN. Close the external shutter if sensitive optical components exist in the output beam path. Proper wavelength calibration of the light power photocell will probably not be maintained.

Information about aborting any requested move and determining the status of the motorized rear plate may be found in Chapter Five, System Description and Control in the section titled: LASER HEAD AND AUTOMATED FEATURES: Motorized Rear Mirror Plate: Changing Single Line Wavelengths.

The "Go to cal position Menu" shown in Figure 9-1 is used to orientate the rear mirror plate to known calibrated positions.

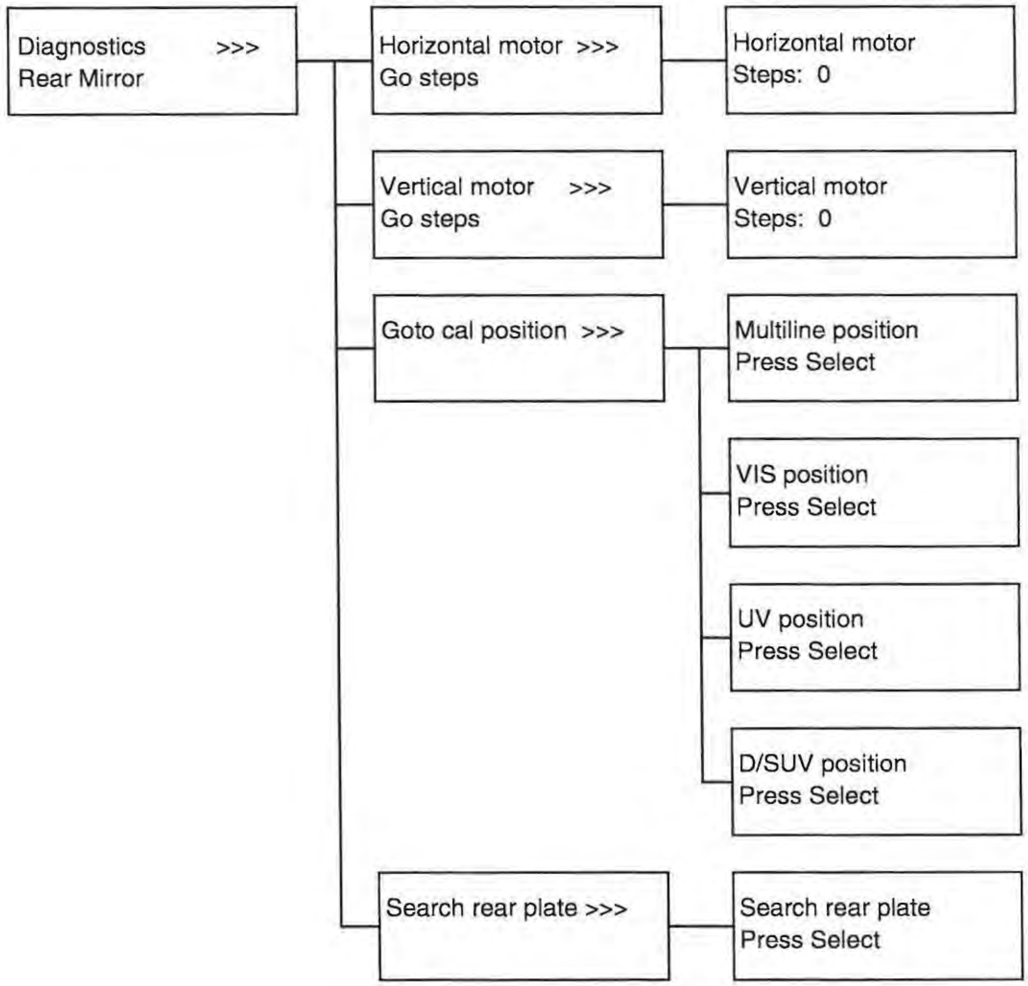


Figure 9-1. Diagnostics: Rear Mirror Menu Tree (Argon)

Selection of any of the lower menu options will drive the rear mirror plate to a known home position (where the photointerrupters are blocked) and then assume alignment at the desired calibrated position. The system will not automatically optimize the alignment for maximum output power if lasing is established.

There are four lower level members of the "Go to cal position Menu" as shown in Figure 9-1. The "Multiline position Menu" should be used when the multiline rear mirror holder is installed. The rear mirror plate will be oriented at the position that corresponds to multiline operation. Alternatively, use external computer control (Command: Motor Home = 0). On argon systems, the "VIS position Menu" should be used when the visible (VIS) single line rear mirror holder is installed. On krypton systems, the top line of the menu will read "VIS/IR

position" and should be used when the VIS/IR single line rear mirror holder is installed. The rear mirror plate will be oriented at the position that corresponds to single line operation at 488.0 nm for argon or 647.1 nm for krypton. Alternatively, use external computer control (Command: Motor Home = 1). The "UV position Menu" should be used when the UV single line rear mirror holder is installed. The rear mirror plate will be oriented at the position that corresponds to single line operation at 351.1 nm for argon or 350.7 nm for krypton. Alternatively, use external computer control (Command: Motor Home = 2). On argon systems, the "D/SUV position Menu" should be used when the D/SUV single line rear mirror holder is installed. The rear mirror plate will be oriented at the position that corresponds to single line operation at 302.4 nm. Alternatively, use external computer control (Command: Motor Home = 3). On krypton systems, the "D/SUV position Menu" is irrelevant. Selection of this menu will then orient the rear mirror plate at a default position.

The "Search rear plate Menu", shown in Figure 9-1, is used to perform a localized search to establish and optimize lasing without driving the rear mirror plate to its known home position. Alternatively, use external computer control (Command: Search = 1).

The "Vertical motor Menu" and "Horizontal motor Menu" selections, shown in Figure 9-1, are used to move the individual vertical and/or horizontal stepper motors a designated number of steps. Use the up/down arrows to scroll to the desired value and press Select to execute the move. Subsequent pressings of Select will re-issue the move command for the designated number of steps. Pressing the MEMORY button will change the sign of the number of steps displayed. Pressing the TUNE button will increment the number of steps positively to the next integral of 2000. A positive number of steps tilts the mirror plate back, away from the head. These menus may be used in either the multiline or single line cavity configuration. External computer control may also be used to control the individual stepper motors (Commands: Vertical Steps = n or Horizontal Steps = n).

One full revolution of the large gear on the rear mirror plate corresponds to approximately 8000 steps. The maximum allowable number of steps of any given move is ±60,000 but should be limited to smaller increments to avoid driving the rear mirror plate too far incurring potential damage to the stepper motors or reduction gears. If the rear mirror plate

reaches its known home position (where the photointerrupters are blocked), then requests for steps taken in the negative direction will not be executed.

Tables 9-3, 9-4, and 9-5 list the relative vertical steps versus single line wavelength for the VIS, UV, and D/SUV argon single line rear mirror holders respectively. Tables 9-6 and 9-7 list the relative vertical steps versus single line wavelength for the VIS/IR and UV krypton single line rear mirror holders respectively. For example, if an argon system is lasing at 514.5 nm, with the VIS single line holder installed, and the requested move is to the position that corresponds to 488.0 nm, then the appropriate number of vertical steps to take is 2792 (= 4116 – 1324). The numbers presented in the tables are nominal values and may or may not correspond to the optimized alignment producing maximum output power when moving from one line to another.

The rear mirror plate may also be moved in the vertical direction only using external computer control (Command: Next Wavelength = n). This command should only be issued when operating in the single line cavity configuration. If n = 1, the vertical motor only will search for and optimize lasing at the next higher wavelength found. The wavelength calibration for the photocell will be changed accordingly based on the best guess of the wavelength found. If n = 0, the vertical motor searches for the next lower wavelength.

Argon VIS Single Line Holder	
Wavelength (nm)	**Relative Vertical Steps (Nominal)**
528.7	0
514.5	1324
501.7	2617
496.5	3171
488.0	4116
476.5	5474
472.7	5944
465.8	6829
457.9	7888
454.5	8368

Table 9-3. Argon VIS Single Line Holder: Vertical Steps versus Wavelength

Argon UV Single Line Holder	
Wavelength (nm)	Relative Vertical Steps (Nominal)
385.8	0
379.5	1480
363.8	5560
351.1	9306
335.8	14481
334.5	14987
333.6	15307

Table 9-4. Argon UV Single Line Holder: Vertical Steps versus Wavelength

Argon D/SUV Single Line Holder	
Wavelength (nm)	Relative Vertical Steps (Nominal)
335.8	0
334.5	502
333.6	819
305.5	13059
302.4	14655
300.3	15798
275.4	31684

Table 9-5 Argon D/SUV Single Line Holder: Vertical Steps versus Wavelength

Krypton VIS/IR Single Line Holder	
Wavelength (nm)	Relative Vertical Steps (Nominal)
799.3	0
752.5	1607
676.4	4735
647.1	6175
568.2	11028
530.9	14038
520.8	14955
482.5	18989
476.2	19744
468.0	20778
415.4	29005
413.1	29444
406.7	30705

Table 9-6 Krypton VIS/IR Single Line Holder: Vertical Steps versus Wavelength

Krypton UV Single Line Holder	
Wavelength (nm)	Relative Vertical Steps (Nominal)
356.4	0
350.7	1740
337.5	6201

Table 9-7 Krypton UV Single Line Holder: Vertical Steps versus Wavelength

Automatic Aperture Motor

The "manual" control of the automatic aperture motor allows the user to move the aperture stepper motor a designated number of steps.

To access the lower level menus, enabling "manual" control of the automatic aperture motor, requires that the extended menus be displayed on the remote (Sabre Power Supply DIP

switch 8 on MY TALK ADDRESS = ON). Navigate the menu tree as shown in Figure 9-2. Use the up/down arrows to scroll to the desired value and press Select to execute the move. Subsequent pressings of Select will re-issue the move command for the designated number of steps. Pressing the MEMORY button will change the sign of the number of steps displayed. A positive number of steps moves the aperture towards a higher-numbered aperture position. External computer control may also be used to control the aperture stepper motor (Command: Aperture Steps = n).

One full revolution of the aperture wheel corresponds to 800 steps. Each aperture position is separated by 40 steps. The maximum allowable number of steps of any given move is ±60,000 but should be limited to smaller increments to avoid incurring potential damage to the stepper motor.

Information about determining the status of the automatic aperture motor may be found in Chapter Five, System Description and Control in the section titled: LASER HEAD AND AUTOMATED FEATURES: Automatic Aperture and TEM_{00} Detector.

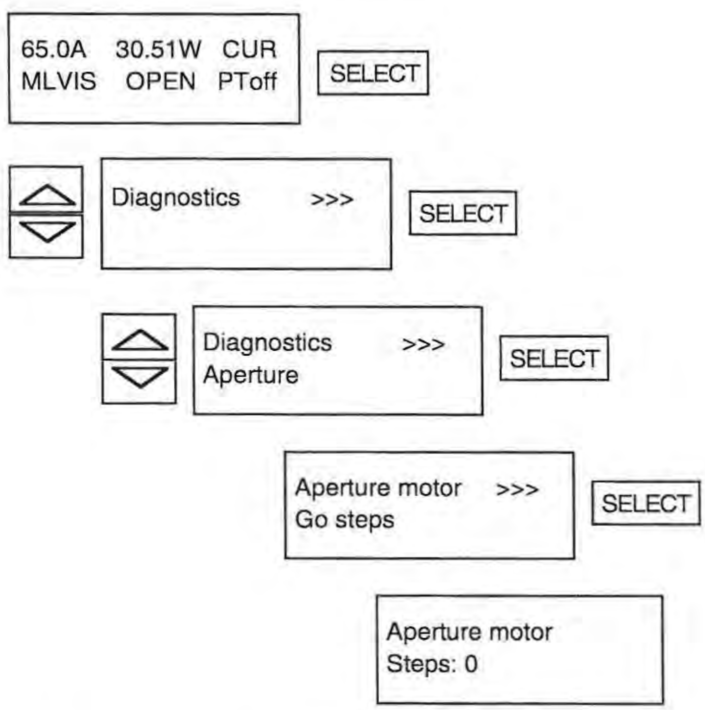


Figure 9-2. Aperture Motor "Manual" Control Menu Path

Operator's Manual

Chapter Ten
Theory of Operation

Coherent

The Noble Gas Ion Lasers

The Sabre ion laser belongs to a class of lasers known as the noble gas ion lasers—so called because the laser light produced is provided by amplification of the radiative electronic transitions of the ionic states of the noble gas atoms. Ion lasers are among the most important sources of coherent radiation in the visible and near-visible spectrum. Extensive research and engineering have been devoted to making ion lasers rugged and reliable.

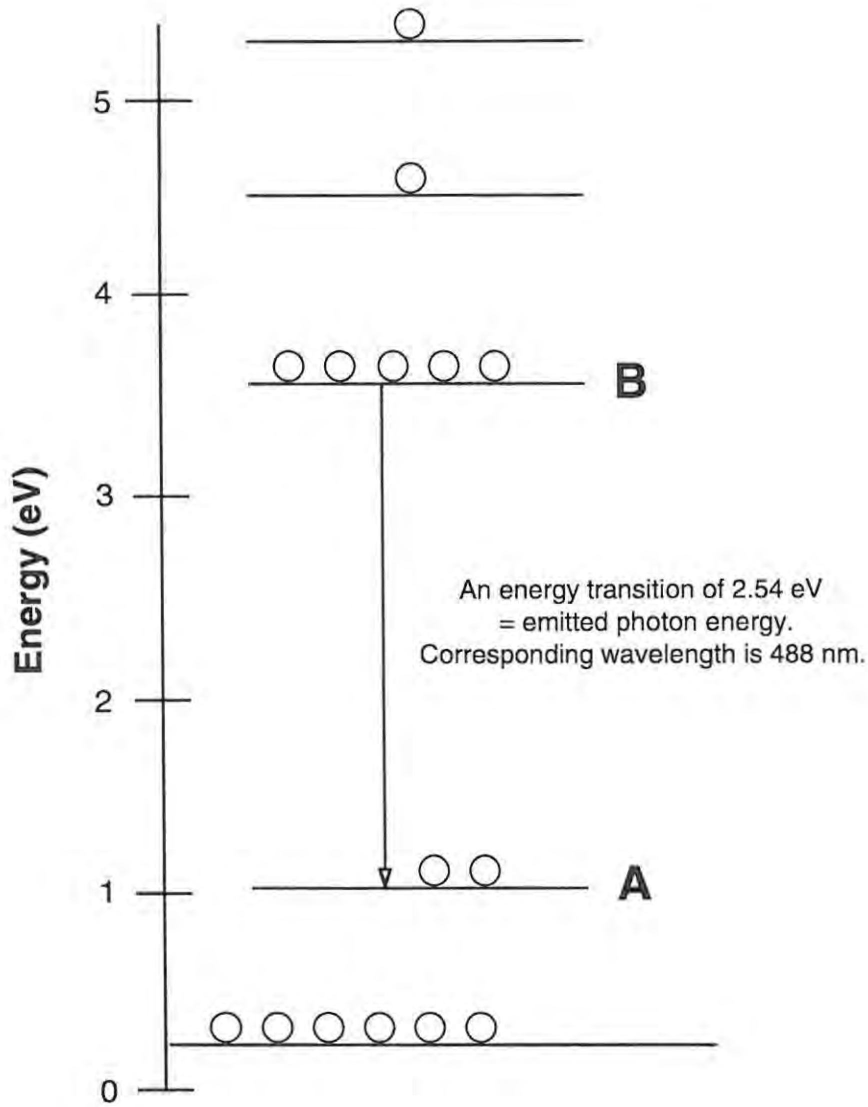
Laser action requires a light amplifier and an optical cavity that stores light energy. Laser light will be produced when the amplifier provides sufficient gain to overcome the loss of the optical cavity.

Gain—The Ion Laser Plasma

The gain in an ion laser originates in a plasma tube, a sealed cylinder containing gas at low pressure. An electric discharge is initiated and maintained through this gas producing a plasma, ionized gas particles and electrons—hence the term ion laser.

Figure 10-1 shows a simple set of energy levels and illustrates the ion laser operation principles. The electrons from the discharge collide with the gas particles, causing them to ionize and become highly excited. The ions relevant to the noble gas ion lasers will have lost anywhere from one to three electrons. The remaining electrons associated with each ion will attain one of many possible discrete configurations that determine the quantum state or energy level of the ion. The ions become distributed in a complex fashion among the various quantum states. Under carefully chosen conditions of current, voltage, and gas pressure, a situation similar to Figure 10-1 will be attained. The number of ions with electronic configuration in some level (B) will exceed the number in a lower energy level (A). This situation is termed population inversion and is necessary for gain in ion lasers. Laser plasma tubes are designed to provide the precisely controlled conditions under which population inversions can be sustained. The greater the population difference between states B and A, the greater the laser gain.

Stimulated emission between state B and state A can induce an ion to release a photon such that the electronic configuration of the ion makes a transition from state B to state A. The energy difference of this transition will be equal to the energy of the emitted photon.



The horizontal lines represent quantum states, the number of circles on each line represents the number of ions in each state. The population in B exceeds the population in A, therefore laser gain can exist at 488 nm. This figure is for illustrative purposes only and does not correspond to the actual energy levels of Ar+.

Figure 10-1. Ar+ Energy Level Schematic

The wavelength, λ, of the emitted photon at which this gain is seen can be expressed by the formula:

$$\lambda = hc/E$$

where E is the energy separation between levels B and A, h is Planck's constant (4.1359×10^{-15} eV sec), and c is the speed of light (2.9979×10^{8} m/sec). In the figure, levels B and A are separated by 2.54 eV, corresponding to a wavelength of 488 nm.

In Figure 10-1, there is only one pair of levels with a population inversion. This figure presents a greatly simplified situation compared to the actual energy level structure of an argon or krypton ion. Argon, for instance, may have as many as one hundred quantum state pairs that simultaneously exhibit population inversions. The wavelengths corresponding to these transitions are called laser lines. The presence of numerous laser lines throughout the visible and near-visible spectrum is one of the virtues of ion lasers. The tables in Chapter Two, System Specifications and Parameters, and Appendix A, Parts List, list the more prominent laser lines that are present in the Sabre ion lasers.

Feedback and Loss—The Optical Cavity

The light energy released through stimulated emission within the plasma tube is stored in the optical cavity of the ion laser. Figures 10-2, 10-3, and 10-4 show a simplified laser cavity in three different configurations. In Figure 10-2, the high reflector mirror with a reflectivity of almost 100%, constitutes one end of the cavity. At the other end is another mirror, known as the output coupler, that reflects slightly less than 100% of the intracavity power. The rest of the light passes through the output coupler to form the output beam. Transmission of light by the output coupler constitutes a loss of energy from the cavity. Laser action will occur only when there is sufficient gain in the tube to overcome the cavity losses.

The cavity mirrors are made by depositing dielectric coatings on a polished surface of quartz or glass. The reflection and transmission properties of these mirrors are controlled by this coating process. Coherent manufactures a line of accessory mirrors to vary the output power and wavelength characteristics of the laser (Appendix A, Parts List).

Optical Cavity Configurations

The laser cavity can be configured in several different ways, illustrated schematically in Figures 10-2, 10-3, and 10-4.

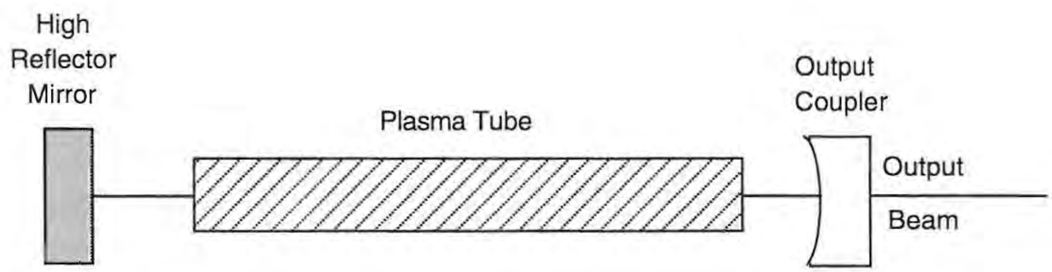


Figure 10-2. Multiline Configuration

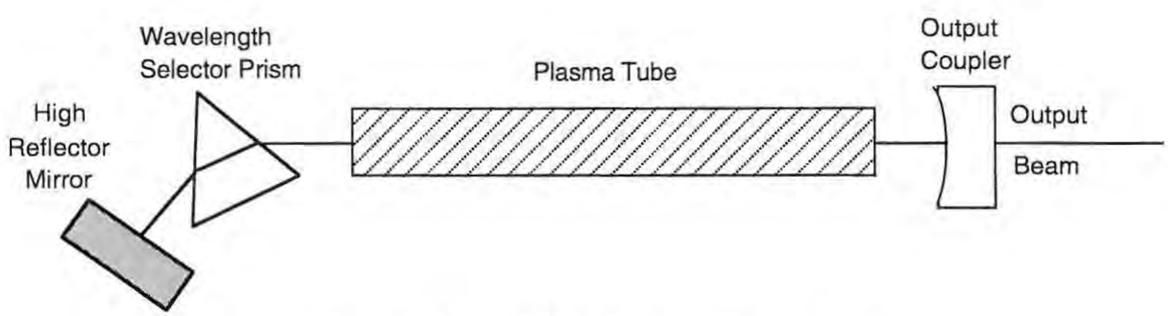


Figure 10-3. Single Line Configuration

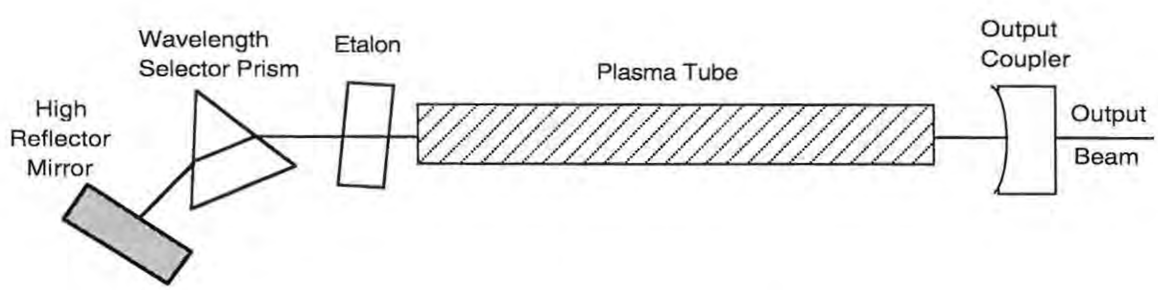


Figure 10-4. Single-Frequency Configuration

Multiline Configuration

In multiline operation (Figure 10-2), the laser operates in a mode where several lines are produced simultaneously. The performance of the laser in this configuration is determined

by the wavelength response of the dielectric coatings of the output coupler and high reflector mirrors. All laser lines within the optical bandwidth of the mirror coatings which have sufficient gain to overcome the cavity losses will oscillate in this cavity.

Single Line Configuration

To achieve single line operation, a prism is placed in the laser cavity and the high reflector is moved off-axis as shown in Figure 10-3. Light striking the prism is dispersed so that only a narrow band of wavelengths can travel back and forth between the high reflector and the output coupler. None of the laser lines outside of the selected band can oscillate in this cavity. If there is only one laser line within the selected band (as is typically the case), the laser will produce output only in the selected single line. There are only a few cases in ion lasers where lines are too close together to be separated in this way.

A comparison of single line and multiline operation reveals an important characteristic of the noble gas ion lasers. Associated with each laser line is a particular pair of quantum energy levels. Laser action has been demonstrated for many sets of energy level pairs in the noble gas ion lasers. However, for the laser lines produced by commercial ion lasers, with a few exceptions, a given upper energy level of the noble gas is utilized by only one laser line. It is more common, however, for the lower level to be shared with other laser lines. Figure 10-5 illustrates this for the case of two argon laser lines (488 and 514 nm) which share a common lower level.

The population inversion is defined as the difference between the populations of the upper and lower levels of a given laser line. The magnitude of the population of each level is determined by a balance between the rates at which ions are added to and lost from a particular level. The population of the upper level can be increased through mechanisms in the discharge which excite the ions to the higher energy levels. These are known as pumping mechanisms. Stimulated emission by the laser is the dominant mechanism to decrease the population of the upper laser level.

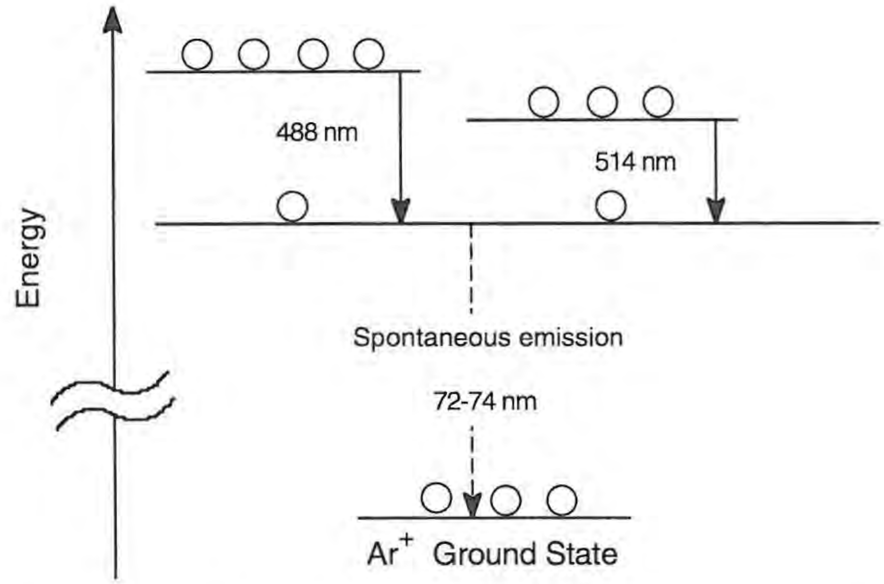


Figure 10-5. Simultaneous Lasing in Two Different Lines

The population of the lower level is increased by some discharge pumping mechanisms as above and is also increased through the transitions from the upper level through stimulated emission. Spontaneous radiative transition to the ion ground state is the dominant mechanism to depopulate the lower laser level of Figure 10-5. The probability for this transition can be up to 25 times larger than the probability at which ions in the upper level make spontaneous transitions to the lower levels. So the magnitude of the population inversion can be dominated by the pumping rate of the upper level, which is set by the current, voltage, and pressure of the discharge, the presence of stimulated emission, and by the rate at which the lower level is depopulated through transitions to the ion ground state.

In Figure 10-5, the rates at which ions are pumped to the upper levels of the 488 or 514 nm lines are not dependent on whether the cavity is in the multiline or single line configuration. They are determined by the discharge parameters. When in the single line configuration tuned to one of the wavelengths, stimulated emission causes ions from the corresponding upper level to make transitions to the lower level. The lower level is then depopulated through transitions to the ion ground state. The population inversion and therefore the gain and magnitude of the output power is determined by the equilibrium magnitude of the population inversion for that line.

When in the multiline configuration, stimulated emission can occur at both lines which causes the ions in each upper level to make transitions to the shared lower level. The population of the lower level is again depopulated through transitions to the ion ground state. The sharing of the lower level produces competition between the laser lines which affects the magnitudes of the respective population inversions of each line. However, since the rate at which the lower level is depopulated is so great, the magnitudes of the equilibrium population inversions of each line and therefore, the output powers, are nearly the same in the multiline or single line configurations.

Selecting a single line with the intracavity prism yields about the same power as externally selecting the same line from a multiline output. Thus, the multiline power is roughly the sum of the single line powers. Due to the sharing of the upper or lower levels, the competition for gain results in a slightly higher sum of the single line powers.

Single-Frequency Configuration

Conventional light sources, such as incandescent lamps, produce light throughout the visible spectrum and thus appear white to the human eye. A single line ion laser, on the other hand, produces light at essentially a single point in the spectrum and thus appears monochromatic. Yet, instrumental measurements of the output of a single line ion laser reveal that it is not monochromatic, but contains a random mixture of closely spaced wavelength components.

Figure 10-6 is a graph of gain versus frequency for a typical ion laser line. This curve, called the gain profile, derives its shape from both the intrinsic properties of the ions and the conditions inside the plasma tube. Measuring the spectral width of this gain profile, where the gain exceeds the losses, gives a quantity called the gain bandwidth, typically about 6 GHz. This is only about one part in 40,000 of the visible spectrum and may be regarded as monochromatic for many practical purposes.

The gain bandwidth is dominated by the velocity distribution of the ions (Doppler width). The magnetic field also is an important factor for broadening the gain curve due to line splitting (Zeeman effect). The relationship between the gain profile and the actual laser output is determined by the laser cavity.

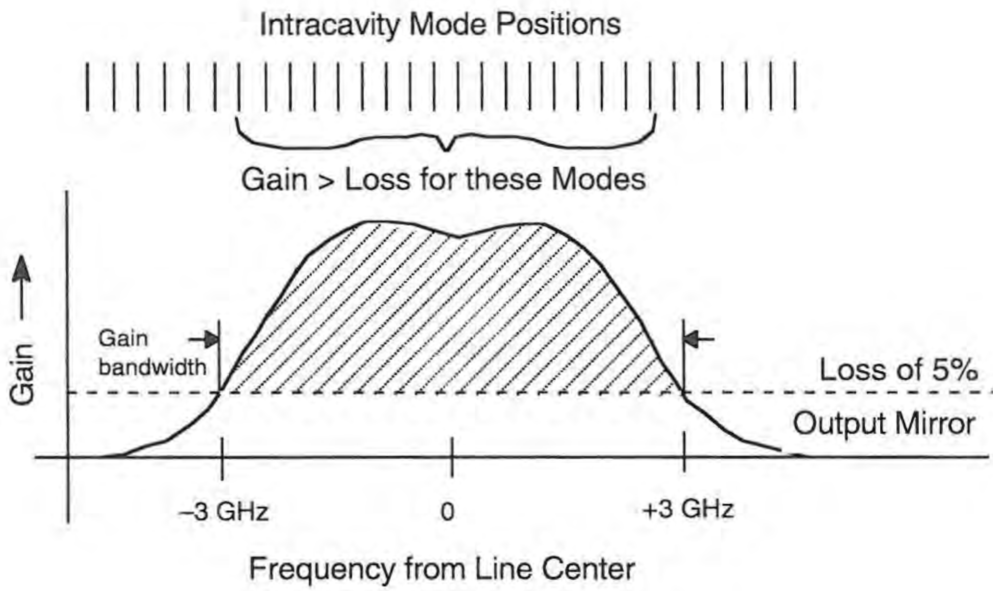


Figure 10-6. Gain Versus Frequency Curve

The cavity has two major effects:

1. Cavity losses suppress laser output on the extreme edges of the gain profile curve. The principal cavity loss, the transmission of the output coupler, is represented by the horizontal line in Figure 10-6. Laser action can only occur at those wavelengths where the gain exceeds the loss, as indicated by the shaded region in Figure 10-6.

2. When an ion laser is operated CW (continuous wave), the light waves inside the cavity form certain standing wave patterns. The cavity modes that support these patterns are comprised of the longitudinal and transverse modes of the resonator. (More information on the transverse modes is given in a subsequent section). The energy stored inside the laser cavity is distributed among the various combinations of the longitudinal and transverse modes. The particular longitudinal and transverse mode components determine the ultimate frequency or wavelength that oscillates and produces output.

   When oscillation is confined to only one transverse mode, (usually selected as the TEM_{00} mode), only certain wavelengths of light are supported by the cavity whose spacings are determined by the longitudinal or axial modes of the cavity. The difference between the wavelengths produced by these longitudinal modes are

related to the cavity length by integral multiples of half wavelengths. Ignoring the effect of the transverse mode, the wavelengths of these modes must satisfy the equation:

$$L = m\,\lambda/2$$

where λ is the wavelength, L is the length of the laser cavity, and m is an integer called the longitudinal mode number.

In the Sabre ion laser, the cavity length is about six orders of magnitude greater than the laser light wavelength. A typical case, L=2.00 meters and λ=488 nm, gives a value for m of about 8×10^6 using the formula above. The difference in wavelength from one mode to the next is only 6×10^{-5} nm. This separation between modes, or mode spacing, is usually specified in frequency units. In the case of the Sabre ion laser, the mode spacing is 75 MHz, much less than the ion gain bandwidth of 6 to 8 GHz. Approximately 80 to 100 modes will satisfy the basic laser condition of gain greater than loss, such that the laser may emit light in all of these modes, as shown in Figure 10-6.

The laser will not, however, support laser action in all of these modes simultaneously because of so called mode competition. Mode competition arises because the homogeneous linewidth within the gain profile is much larger than the mode spacing. Homogeneous linewidth in this case means, that all ions capable of emitting within that linewidth can provide gain to one laser mode. The strongest mode within the homogeneous linewidth will therefore consume all the available gain and thus eliminate neighbor modes. Other modes outside the homogeneous linewidth will lase simultaneously. The total gain bandwidth, given by the convolution of homogeneous and inhomogeneous linewidth contributions from different line broadening effects, is much greater than the homogeneous linewidth.

For many applications, the presence of multiple modes within one laser line is acceptable. However, certain physical phenomena can be obscured by the interference between these modes. To circumvent this problem, single-frequency operation can be achieved by the use of an intracavity etalon (Figure 10-4). In this configuration, laser action will occur in only a single cavity mode.

The etalon used in the Sabre ion laser consists of a solid piece of fused silica with two polished parallel surfaces. These polished surfaces may also have a dielectric coating applied to control the transmissive properties of the etalon. Three

different etalons are used in the Sabre. The thickness of the etalon is either 10 mm (0.400 inches) or 7.95 mm (0.313 inches). The etalon will produce multiple transmitted and reflected beams through reflections at the air to fused silica interface. Figure 10-7 shows the primary transmitted and reflected beams as well as the secondary transmitted beam. Higher order reflections have been omitted for clarity.

All transmitted beams will constructively interfere if the path length difference with respect to that of the primary beam is an integral multiple of the wavelength. The interference will be destructive for a path length difference which is an odd integral multiple of half wavelengths. The path length difference depends on the wavelength, tilt angle, and the temperature of the etalon optic.

As the wavelength is varied minutely with a constant tilt angle and temperature, the transmission through the etalon goes through maxima and minima, and the etalon induced loss follow an inverse pattern as shown in Figure 10-8.

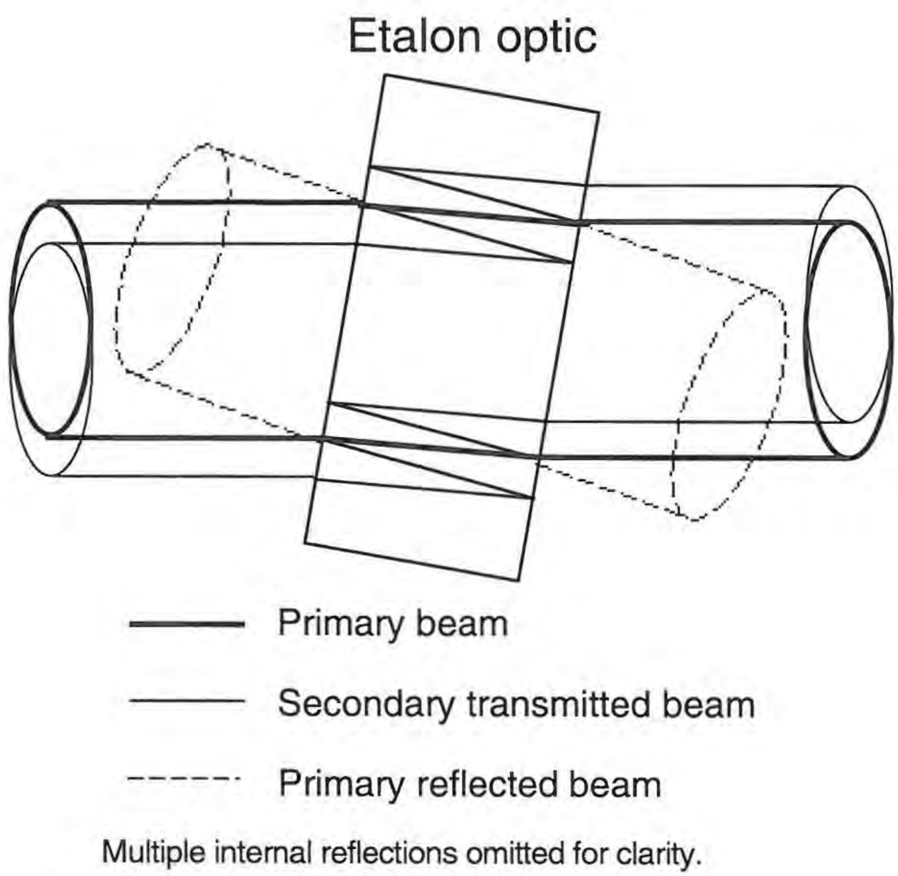


Figure 10-7. Intracavity Etalon

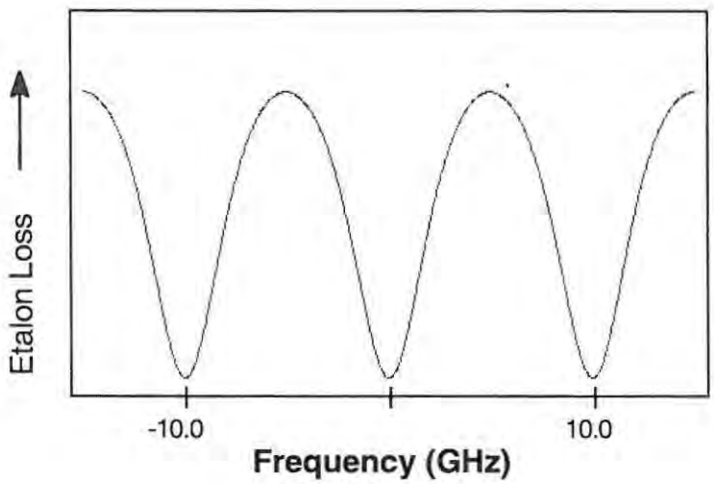


Figure 10-8. The Etalon as a Frequency Filter

The losses close to the transmission maxima are nearly zero, as indicated in Figure 10-8. The 'walk-off' loss dominates the total loss close to the minimum of the loss curve, while the loss due to destructive interference dominates the rest of the curve. The actual tilt angle is selected to be much smaller than that depicted in Figure 10-7 (approximately 2.5 mrad) to keep the 'walk-off' loss per round trip below 0.05% for the coated 10 GHz etalon, below 0.009%for the uncoated 10 GHz etalon, and below 0.006% for the uncoated 13 GHz etalon.

The maximum loss between two transmission maxima depend mainly on the etalon coating used. For a 20% reflective coating, for example, these losses are approximately 56%.

When an etalon is placed inside an ion laser cavity, its filtering properties can be used to suppress unwanted longitudinal modes from lasing. Figure 10-9 shows an etalon loss curve, a laser line gain curve, and the longitudinal mode frequencies for a simplified Sabre ion laser operating situation. In the diagram, the single longitudinal mode, illustrated by the dotted line, suffers lower loss due to the etalon than its neighboring modes. The etalon transmission curve has to be selected such that the frequency range where gain exceeds the etalon loss is smaller than the homogeneous linewidth. Typically, the strongest mode within that range will suppress all other modes through mode competition.

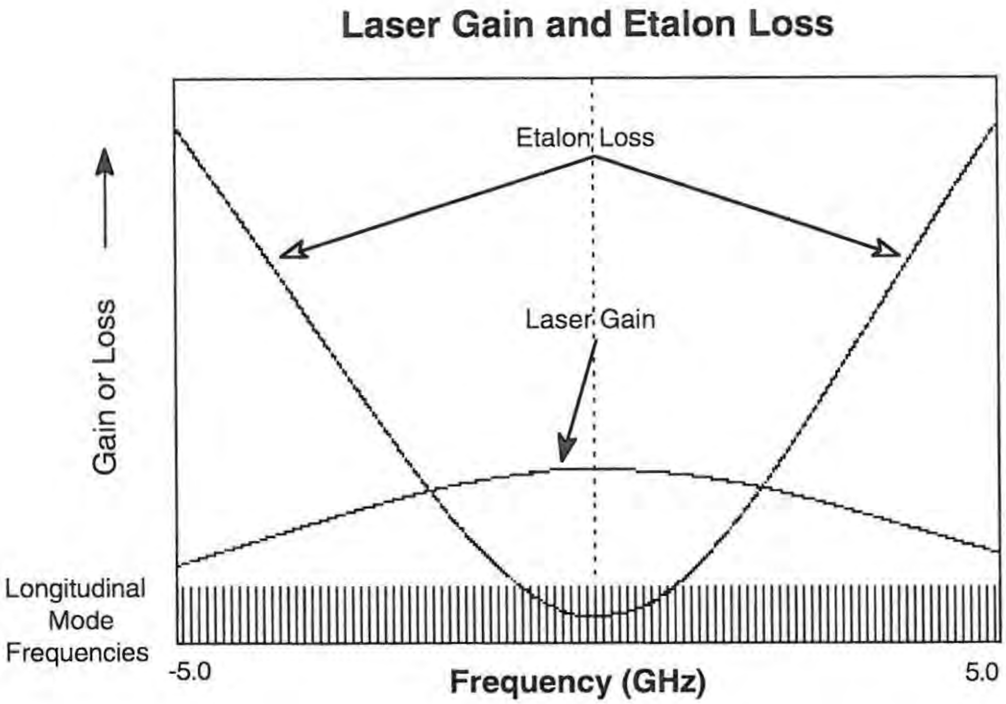


Figure 10-9. Etalon Loss and Laser Gain

Figure 10-9 shows the etalon aligned near the peak of the laser gain curve. This situation typically provides the highest single-frequency power. Single-frequency operation is not, however, limited to operation close to the gain maximum.

In general, as the temperature inside the laser head changes, the cavity length will increase or decrease and the frequency of the longitudinal mode will change. As the frequency of the selected mode drifts from the minimum of the etalon loss curve, the output power may drop as much as 20% and a neighboring mode may exhibit a larger difference between gain and loss. Under these circumstances, the laser frequency will suddenly jump to the neighboring mode. This event is called a mode hop. After a mode hop, the output power will return approximately to maximum. The difference in frequency between the initial and final modes will be a multiple (usually 1) of the 75 MHz longitudinal mode spacing. When the laser head is thermalized, mode hops may also be induced by manually changing the etalon temperature which will move the etalon loss curve in frequency with respect to the gain curve and the longitudinal mode positions.

When the laser is first started, even with the etalon fully warmed-up, mode hops may occur every few minutes. The

number of mode hops will decrease as the laser head warms up and stabilizes. Once warmed-up, mode hops may still occur if the temperature of the ambient air or cooling water changes by as little as 0.5 °C. If the etalon is installed into a head that is already warmed-up, then mode hops can also be expected during the etalon warm-up period (approximately 15 minutes). Prevention of mode hops in these situations, requires of the operator to monitor and maximize the output power by making adjustments to the cavity length and/or the etalon temperature. These procedures may be done manually by varying the cavity length Z-axis DAC or the etalon temperature or automatically by using the built-in ν-Track or ModeTrack routines described in subsequent sections.

Successful single-frequency operation may be attained by adjustment of the etalon loss curve such that its minimum corresponds with the desired longitudinal mode. That mode will then demonstrate constructive interference in transmission through the etalon. The etalon used in the Sabre ion laser is enclosed in a temperature controlled housing. Changing the etalon temperature alters the index of refraction of the fused silica and therefore changes the optical path through the etalon. Adjustment of the etalon temperature thus shifts the etalon loss curve of Figure 10-9, allowing the etalon to be tuned to the desired mode. An increase in the etalon temperature will shift the etalon loss curve to a lower frequency. While tuning the temperature of the etalon, the etalon loss minimum will slowly drift away from the lasing longitudinal mode, causing power loss. At some point, another cavity mode will suddenly start lasing (mode hop) closer to the minimum of the etalon loss curve. The relative single-frequency powers of the individual longitudinal modes will generally follow the gain curve shape so that the highest single-frequency powers may be attained by the modes nearest to the gain maximum.

When the minimum of the etalon loss curve is tuned to the outer edge of the gain curve, the possibility exists that two modes may exhibit differences between gain and loss such that both modes lase simultaneously. This is due to the fact that the etalon loss curve is periodic in nature (Figure 10-8). Minima of the etalon loss curve are separated by the free spectral range of the etalon transmission function. The approximate separation of these minima for the etalons used in the Sabre are either 10 or 13 GHz. The output power in two mode oscillation can in some cases be relatively high and may generally follow a shape similar to the gain curve as the etalon is tuned in temperature. The peak power of two mode

oscillation, however, is usually of a smaller magnitude than that produced by single-frequency oscillation near the peak of the gain curve.

Successful single-frequency operation may also be attained by adjustment of the longitudinal mode spacing such that the desired longitudinal mode corresponds with the minimum of etalon loss curve. That mode will then demonstrate constructive interference in transmission through the etalon. Changing the resonator cavity length alters the longitudinal mode spacing which effectively shifts the frequency of a given lasing mode with respect to the etalon loss curve. An increase in the cavity length will shift the lasing longitudinal mode to a lower frequency. Variation of the cavity length in the Sabre ion laser is accomplished through longitudinal displacement of the output coupler.

Manual Etalon Temperature Operation

Manual etalon temperature operation is a basic mode in single-frequency operation where the operator can manually adjust and set the etalon temperature which is then held fixed at that value. In this mode, the etalon loss curve shifts and then remains fixed in frequency with respect to the laser gain curve and the longitudinal modes. The operator will usually manually tune the etalon temperature such that the single-frequency output power is maximized.

It is not recommended to use light regulation when operating in manual mode unless the laser is well warmed-up and stabilized. Otherwise, the laser current will rise and fall appreciably with mode hops. This may result in light regulation running out of range as well as preventing thermal stabilization of the laser.

Manual Z-axis DAC Operation

Manual Z-axis DAC operation is a basic mode in single-frequency operation where the operator can manually adjust and set the cavity length through adjustment of the Z-axis DAC. A higher value of the Z-axis DAC corresponds to a longer cavity length which in turn shifts the lasing mode to a lower frequency. For small changes in cavity length, the lasing longitudinal mode shifts and then remains fixed in frequency with respect to the laser gain curve and the etalon loss curve. For large changes in cavity length within the homogeneous linewidth, the lasing longitudinal mode may shift to a frequency corresponding to the change in cavity length or the laser frequency may mode hop, due to a disturbance such as noise, to a longitudinal mode exhibiting a

larger difference between gain and loss near the minimum of the etalon loss curve. The operator will typically manually adjust the Z-axis DAC to maximize the single-frequency output power.

ModeTune

ModeTune is an automatic tuning that finds and sets the etalon temperature to achieve the maximum output power. For maximum single-frequency output power, the minimum of the etalon loss curve must be aligned near the peak of the laser gain curve.

Simultaneous adjustment of the etalon temperature and cavity length can be used to shift the etalon loss curve and the lasing longitudinal mode in frequency such that the lasing longitudinal mode is maintained at the minimum of the etalon loss curve. The output power of that mode will then be maximized as the frequency is scanned. The resulting envelope of the output power will generally follow the shape of the gain curve.

The ModeTune routine scans the etalon temperature through its entire temperature range, while the cavity length is continually adjusted, looking for a maximum value of output power. Since the total frequency range scanned by the etalon is much greater than the adjustment range of the cavity length Z-axis, the cavity length Z-axis DAC must be reset periodically to the center of its range and optimized to find another longitudinal mode at the minimum of the etalon loss curve. After the temperature scan, the etalon temperature is returned to a value corresponding to the peak output power. A routine similar to ModeFineTune, described in the following section, is then initiated to slowly vary the etalon temperature, while optimizing cavity length, to a temperature corresponding to maximum output power. When the routine is finished, the ν-Track routine is automatically engaged.

ModeFineTune

ModeFineTune is a ModeTune subroutine that precisely searches for and sets the etalon temperature to achieve the maximum output power. While ModeFineTune is automatically incorporated into ModeTune, it can also be accessed separately. ModeFineTune can be used to ensure that single-frequency operation is at an etalon temperature that produces a maximum output power.

When ModeFineTune is activated, it will slowly scan the etalon set temperature over a narrow temperature range while sampling the output power. The cavity length is

simultaneously optimized for maximum power during the scan. Upon completion, it will set the temperature to the optimum value and automatically engage the ν-Track routine.

ModeTrack

When operating with a fixed etalon temperature, variations in resonator temperature can cause the lasing longitudinal mode to shift in frequency with respect to the etalon loss curve causing large power fluctuations and unpredictable mode hops. ModeTrack is an active stabilization loop that continuously adjusts the etalon temperature to lock onto and track the drift of the lasing longitudinal mode, thereby preventing mode hopping. Frequency drift is directly determined by the amount of temperature change seen by the resonator (long-term change). A very small power modulation of output power will be present since ModeTrack continuously dithers and adjusts the etalon temperature to maintain the maximum possible output power. The output power modulation may be eliminated by operating in Light Regulation Mode. ModeTrack can be initiated at any time and can be engaged after completion of the ModeTune or ModeFineTune routines described in the preceding sections.

ν-Track

Variations in resonator temperature can cause cavity length changes. The resulting shifts in frequency of the lasing longitudinal mode with respect to the etalon loss curve may cause large power fluctuations and unpredictable mode hops. It is possible to nullify the induced frequency shifts by actively adjusting the cavity length. ν-Track is an active stabilization loop that continuously adjusts the cavity length to lock onto and track the drift of the etalon temperature, thereby preventing mode hopping. Any frequency drift is then determined directly by the temperature stability of the etalon. The stability of the etalon temperature is typically excellent resulting in an elimination of any frequency drift. A very small power modulation of output power will be present since ν-Track continuously dithers the etalon temperature to produce an error signal that drives cavity length corrections. The output power modulation may be eliminated by operating in Light Regulation Mode. ν-Track can be initiated at any time and is engaged automatically after completion of the ModeTune or ModeFineTune routines described in the preceding sections.

To ensure actual single-frequency operation requires the use of a scanning interferometer (Coherent Model 240 spectrum analyzer). If a scanning interferometer is not available, then it

may be possible to attain single-frequency operation by tuning the etalon through a frequency range exceeding its free spectral range while observing the output power. Readjusting the etalon set temperature to the value that was observed at the maximum output power may correspond to single-frequency operation near the peak of the gain curve. This procedure may be done manually or automatically using the ModeTune and ModeFineTune routines described in the previous sections.

Linewidth

The term linewidth must be used with care when describing the output of a single-frequency ion laser. Unavoidable mechanical variations of the laser resonator cause the frequency of the selected cavity mode to vary with time. The effective linewidth for any physical interaction between the laser light and other materials depends on the range of frequencies that occur during the time period of the measurement This concept is particularly important for applications—such as holography—that depend on the long-term phase coherence of the light. This property of the laser output is described as coherence length, defined by the following formula:

$$S=c/\Delta\upsilon$$

where S is the coherence length, c is the speed of light and $\Delta\upsilon$ is the FWHM of the laser frequency range (during the time period of the measurement). This coherence length is the maximum path length difference over which two beams, split from the same laser, will form an interference with good contrast ratios.

An important source of frequency variation in ion lasers is slow drift stemming from thermal changes in the laser resonator. As the spacing between the cavity mirrors changes (through expansion or contraction of the laser resonator), the frequency position of the cavity modes will change. The frequency of the selected mode will therefore drift. The rate of drift depends on the environment of the laser head, including the temperature and pressure of the cooling water and the temperature of the air that surrounds the head. Best static performance will be seen when the laser has been thoroughly warmed-up (for a minimum of two hours) at a constant current and is located in an optimized environment with stable ambient temperature and cooling water. Alternatively, frequency drift may be actively minimized through the use of the ν-Track routine in situations with varying environmental conditions.

Output Beam Size

Laser light does not focus to a point but to a spot of finite diameter at a position called the beam waist. Moving away from the waist, the beam will gradually increase in size at a rate given by its divergence.[1]

The optics of the laser cavity determine the waist position, beam diameter, and divergence of the output beam. For example, the standard Sabre Argon ion laser cavity consists of a flat high reflector and a 15 meter (49 ft.) radius of curvature output coupler. This simple cavity produces a waist at the high reflector and a divergent intracavity beam at the reflecting surface of the output coupler optic. The output coupler acts as a slightly negative lens with respect to the output beam, (it consists of a concave reflecting surface and a flat exit surface), causing the beam to behave as though it had a waist 0.52 meter (1.7 ft.) behind the high reflector. The values for the beam diameter and beam divergence at the exit surface of the output coupler given in Tables 2-7 and 2-8 include the weak lens effect. The values for the virtual beam waist location and diameter are also presented in Tables 2-7 and 2-8. Use these values to estimate the behavior of the Sabre beam as it propagates through optical elements such as lenses or mirrors.

Polarization

One or both ends of the INNOVA plasma tube are sealed with crystalline quartz windows that allow the intracavity beam to propagate through the plasma region. The window is carefully oriented such that the angle between the direction of propagation of the beam and the normal of the surface of the window is at Brewster's angle. At this special angle, light, whose electric field vector lies in the plane determined by the propagation vector and the surface normal, will experience zero surface reflection loss. The polarization perpendicular to this plane will suffer sufficient loss such that it will not be sustained within the laser cavity. The Brewster windows thus serve two functions: it keeps the cavity losses as low as possible and also provide a polarized output beam.

Transverse Modes

The electromagnetic energy stored in the laser cavity is distributed among the various combinations of the longitudinal and transverse cavity modes. Transverse mode patterns may be observed by examining the intensity of the cross section of the beam at any distance along the beam path.

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1. For a more complete discussion of this subject, see: Siegman, Anthony E. *Lasers*, Mill Valley, CA: University Science Books, 1986.

In the simplest of these patterns the maximum light intensity is found at the center of the beam. As the distance from the center increases, the intensity falls off smoothly and uniformly. This is the so-called Gaussian or TEM_{00} mode. More complex patterns also exist and are collectively termed higher-order modes. Some examples and their designations are illustrated in Figure 10-10. (For ease of presentation, black regions in Figure 10-10 represent higher intensities). Note that some of these modes have a center with a reduced intensity. The typical mode patterns exhibit the cylindrical symmetry of the ion laser cavity.

Analogous to the longitudinal modes discussed in a preceding section, the boundary conditions determined by the resonator's optical configuration can support certain transverse modes. For a given longitudinal mode, each transverse mode has assigned to it a mode number and corresponding frequency of oscillation. The resonator may support simultaneous lasing in several transverse modes. True single-frequency operation, therefore, will require selection of a single transverse mode, usually the TEM_{00} mode, as well as selection of a single longitudinal mode.

The TEM_{00} mode is of special interest, since it has the smallest diameter of any of the transverse modes and will propagate through optical systems (lenses and mirrors) in close agreement with the formulas of Gaussian optics. For applications that require extremely tight focusing of the output laser beam, TEM_{00} mode operation is essential.

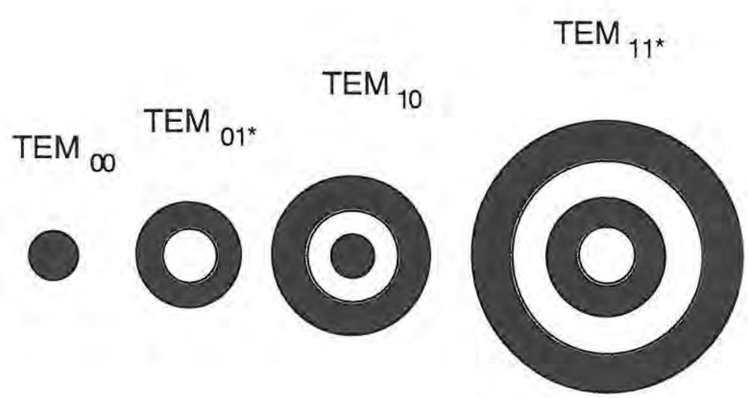


Figure 10-10. Transverse Electromagnetic Beam Profiles

In the Sabre, TEM_{00} mode operation is achieved through the use of an adjustable intracavity aperture. The aperture is comprised of a rotatable wheel with a set of holes of different diameters which can be oriented to intersect the intracavity beam path.

This aperture discriminates against higher-order modes by exploiting the somewhat small diameter of the TEM_{00} mode. The lower numbered settings on the aperture correspond to the smaller holes which can introduce more loss to the higher-order modes. The optimum aperture setting may be manually selected by systematically choosing smaller holes while observing the intensity profile of the output beam.

Alternatively, the Sabre ion laser can automatically find the appropriate aperture setting which results in oscillation of a single transverse mode, usually the TEM_{00} mode. The TEM_{00} detector takes advantage of the fact that different transverse modes oscillate at different frequencies. By sampling a portion of the output beam, variations in intensity caused by the beating of these frequencies together can be detected. The Sabre systematically chooses smaller aperture holes while monitoring the mode beating until a only a single transverse mode is present. The resulting output mode is almost always, but not necessarily, the Gaussian or TEM_{00} mode.

Laser generation at the argon line 488.0 nm presents a special case in interpretation of the TEM_{00} detector's indication. For all other laser lines, indication by the TEM_{00} detector implies that a single transverse mode is oscillating. That mode is almost always the TEM_{00} mode and M^2 will be less than or equal to 1.1, implying a nearly Gaussian transverse mode profile. In the case of 488.0 nm, when aperturing down to produce a nearly Gaussian profile, there can still be a very small amount of a higher order mode, most likely the TEM_{01^*}, also oscillating.

The gain of the TEM_{00} detector, operating at 488.0 nm, has been calibrated to indicate TEM_{00} operation when the M^2 becomes less than or equal to approximately 1.3 and will not necessarily imply single transverse mode operation. Visually, and in relation to beam propagation where focusing is important, the overall mode can be considered to be Gaussian for all intensive purposes when TEM_{00} is indicated. It is possible to attain truly single transverse mode oscillation, important in single-frequency operation, by further reducing the aperture setting.

The indication of the TEM_{00} detector while operating in the multiline cavity configuration implies that all laser lines

present are oscillating with single transverse modes. Since each line typically requires a different aperture setting to individually attain single transverse mode oscillation, the aggregate of all lines oscillating simultaneously will require the strict condition that the required aperture setting will be that of the individual line which requires the smallest aperture setting. This strict condition is imposed on argon MLVIS, of which 488.0 nm is a large component, resulting in an over-aperturing and a reduction in available output power. The same argument applies to other multiline wavelength ranges as well. With respect to Gaussian propagation, a higher aperture setting, than that indicated by the TEM_{00} detector, will usually be sufficient.

Single transverse mode oscillation, for all wavelengths, may be verified by clipping the beam in half transversely, sampling the intensity with a fast photodiode, and examining the output on an electronic spectrum analyzer. No resonant peaks should be observed within a bandwidth of 0 to 20 MHz when single transverse mode oscillation occurs. The transverse mode may also be examined visually. It is possible to verify single transverse mode when operating in the single frequency cavity configuration, for all wavelengths, by monitoring the output of the Model 240 optical spectrum analyzer. Transverse modes usually appear on the oscilloscope output as small satellite peaks adjacent to the main peak.

Since TEM_{00} operation is attained by introducing additional loss to the cavity, it necessarily involves a reduction in output power. Maximum output power is obtained with the aperture fully open and the laser producing a multimode beam.

Care must be taken when observing the laser mode since a small intracavity aperture introduces a diffraction pattern onto the output laser beam. This pattern appears as a set of concentric dark rings on the beam profile. The rings disappear at a large distance (> 5 meters [16.4 ft.]) from the laser head. At certain distances—determined by the diameter of the aperture and the wavelength of light—the diffraction pattern will have an intensity minimum on the beam axis causing the center of the beam to appear dark. This condition is not indicative of a higher-order laser mode, which would maintain its dark center at all distances from the laser.

System Components

The Magnet

The plasma tube in the Sabre ion laser is enclosed in an axial electromagnet which produces a magnetic field inside the plasma tube. This field exerts a force on the ions which confines them to the center of the tube, thereby increasing the laser gain. At the same time, however, the magnetic field introduces an energy splitting of the quantum levels that produce the laser gain. This Zeeman effect is a major contributor to the gain bandwidth of ion lasers.

The Plasma Tube

The Series V plasma tube in the Sabre ion laser is the result of years of technological evolution and represents the state-of-the-art in ion tube design. An ion laser tube must meet several demanding requirements: it must control and confine an electrical discharge whose current density is on the order of 700 amperes per square centimeter; it must efficiently conduct heat from the tube bore to the surrounding cooling water; it must be vacuum tight and have electrically insulating walls; and it must maintain a uniform gas pressure at the level which gives the highest laser gain. These design criteria must be met in a manner consistent with component reliability and long operating life.

At the center of the tube is an open region called the tube bore. At one end of the bore is the cathode where electrons are emitted. A series of metal disks extends throughout the length of the tube confining the plasma to the center of the bore. The electron path terminates at the anode.

The disks are made of tungsten, a material with two favorable properties: a high resistance to melting under the extreme heat load produced in the plasma and a high resistance to sputtering under the impact of ionized gas particles.

The disks are surrounded by a vacuum sealed ceramic envelope which efficiently conducts the heat built up in the disks. The outside of the ceramic is cooled by direct contact with a flow of cooling water. This metal/ceramic construction ensures mechanical strength and ruggedness. The vacuum envelope is formed of a single seamless cylinder of alumina ceramic, chosen for its combination of mechanical strength, electrical insulation, and thermal conductivity.

All ion laser plasma tubes suffer a slow loss of gas pressure during operation and must include a means of maintaining the optimum pressure over the lifetime of the tube. On the

Sabre ion laser, this is accomplished by means of an auxiliary gas reservoir and an electronically activated fill system. When circuitry in the power supply senses a drop in gas pressure, it automatically activates the fill mechanism to replenish the gas inside the plasma tube. This Autofill system ensures that the tube pressure will be maintained without attention from the laser operator.

The Resonator

Like any laser, the performance of the Sabre is extremely dependent on the optical alignment. To obtain the maximum output power from the laser, two conditions must be fulfilled:

1. The high reflector and output coupler must be precisely aligned to each other—should either optic be rotated by as little as ten microradians from its optimum orientation, an easily detectable loss of power will occur.

2. The plasma tube must be precisely centered on the axis defined by the two optics. Moreover, when the laser is operated with an intracavity etalon, stability of the cavity length is also extremely important.

This sensitivity to alignment places stringent demands on the mechanical components which secure the optics and plasma tube during operation. These components, collectively termed the resonator, can be affected by thermal changes and vibration. The resonator design must take into account not only the demands of optical alignment, but also that the laser head is an active environment containing a 35 kW tube discharge and a 23 liter (6 gallons) per minute flow of coolant.

The resonator structure of the Sabre uses Super Invar, a material that combines excellent mechanical rigidity with a low coefficient of thermal expansion. Three rods of Super Invar form the framework to which the optical mounts are attached. While the low coefficient of expansion helps to maintain the cavity length, flexure mountings and dampers provide the greatest possible vibration isolation for the laser mirrors. The resonator frame is mounted to the laser head by flexure mounts that allow thermal expansion of the magnet and resonator without affecting the optical alignment of the cavity. The magnet is secured to the baseplate by a fixed mount at one end and by a flexure mount at the other. This design permits thermal expansion of the magnet without exerting force on the baseplate or resonator structure.

When the laser is first started up, components in the laser head enclosure experience thermal changes. Until the entire

head reaches a steady state, changes in alignment may occur that noticeably affect output power and beam direction. The rate at which steady state is approached depends on many environmental factors, but small thermal changes can be detected as long as to two to four hours after the laser is initially started up. For most applications a half-hour warm-up is sufficient; for extremely critical performance, a longer warm-up may be necessary.

During operation, the laser alignment will be affected by changes in the cooling water temperature and flow rate, the ambient air temperature and also by changes in the laser operating current. These effects may not be significant for any but the most critical single-frequency applications.

PowerTrack

PowerTrack provides automatic, servo-controlled alignment for the output coupler, to determine and maintain the tilt angle of the output coupler which gives the maximum output power. With the PowerTrack servo engaged, the laser will produce optimum power even during the warm-up period. An additional benefit of the improved resonator alignment is a typical reduction in output amplitude noise.

Two pairs of electromagnetic actuators control the tilt of the output coupler about two axes. The effect of the actuators is to tilt the output coupler back and forth (dither) at a frequency of 30 Hz. The size of the dither is chosen to be extremely small, introducing a modulation of the laser output power that is much less than the intrinsic amplitude noise of the laser.

While the frequency spectrum of the intrinsic noise is quite broad, the PowerTrack modulation occurs at the single frequency of 30 Hz with a known phase angle. Therefore, the PowerTrack information can be effectively extracted from the noise by sampling the laser output beam (using the same laser head photodetector employed in the light regulation circuit) and passing the resulting signal through a 30 Hz filter. The filtered output is then processed by precision analog circuitry to generate the PowerTrack error signals, which in turn are fed to the actuators to maintain optimum mirror alignment. Using the dither-and-track detection method, PowerTrack achieves high sensitivity without introducing unwanted beam noise. By the nature of the dither-and-track method, PowerTrack operates only when the laser is lasing.

The Intracavity Space

During the operation of any high-powered ion laser, photochemical conversion of oxygen to ozone can take place in the beam path. Gradual build-up of ozone within the cavity will cause a serious degradation of laser power. Degradation is avoided in the Sabre by surrounding the intracavity beam path between the Brewster windows and the mirrors with a set of sealed beam enclosure tubes. These tubes incorporate a catalyst which decomposes ozone. This catalytic system provides a clean environment for the laser optics.

The Power Supply

The main function of the Sabre power supply is to provide a properly conditioned flow of current through the plasma tube. The design of the power supply is therefore dictated by the electrical characteristics of the tube.

When the plasma tube is ionized, it offers a resistance to current flow. The associated voltage drop is termed the tube voltage, which is a complex function of the amount of current flowing through the plasma discharge and the pressure of the gas inside the tube. The resistance of the tube does not obey Ohm's law and must therefore be characterized in terms of a dynamic voltage/current relationship. This relationship is known as the V-I curve, a typical example of which is illustrated in Figure 10-11. Under the operating conditions of the Sabre, this curve is nearly linear, but with a slope considerably less than the ratio V/I at any point. For this reason, a stable laser output is more readily obtained by current regulation rather than by voltage regulation of the tube drive circuit.

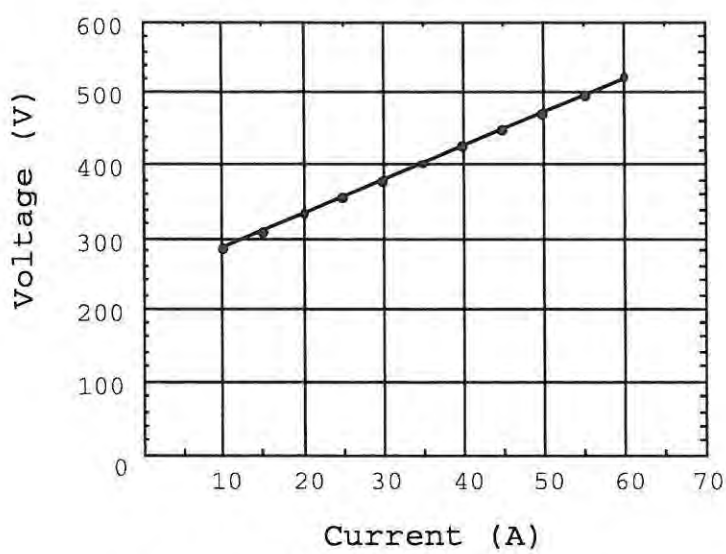


Figure 10-11. Typical V-I Curve

The entire V-I curve shifts downward as the gas pressure inside the tube drops. This phenomenon is the basis for the Autofill system, which activates the gas fill mechanism when it detects a low tube voltage. This downward shift of the V-I curve with gas pressure is most pronounced at high tube currents and therefore, the most accurate pressure readings are obtained at high current. To protect against possible inaccuracies, the CPU disables the Autofill when the tube current is below 20 Amps.

The V-I curve bends sharply upward at very low current, and at zero current the tube exhibits a large resistance to current flow. To start the tube, the cathode filament is switched on and brought to its proper operating temperature. This requires approximately 75 seconds and is called the start delay. A starter circuit then applies a brief pulse of high voltage across the tube to produce ionization. The current regulation circuitry then takes over control of tube operation.

A simplified diagram of the power supply is shown in Figure 10-12. Incoming three-phase power is rectified and passed through an LC filter, generating a positive (B+) and negative (B–) DC voltage. The magnet is connected directly across these points.

The tube and the current regulator are in series from B+ to B– and therefore, the voltage drops across these two circuit elements must sum to the potential difference between B+ and B–. At low tube currents, the tube voltage is relatively low, and the current regulator voltage drop is comparatively high.

Current regulation is provided by a linear passbank, represented on the simplified schematic as a single passbank transistor. A current sensing resistor provides a low-voltage signal proportional to the current. This signal is fed to the comparator, which drives the base of the passbank transistors. The reference for the comparator is an adjustable voltage set by the microprocessor. Thus, the supply maintains a constant current flow through the tube. This mode is called Current Regulation Mode. Alternatively, a photocell is used to sample the laser output power which is compared to a set point. The error signal is used to adjust the reference level on the current regulator, providing feedback stabilization of the laser output power. This mode is called light regulation mode. Both Current and Light Regulation Mode are available under the CPU control on the Sabre.

In addition to the main functions described here, the power supply CPU also monitors a set of safety interlocks and

provides a readout of faults, and operating system parameters.

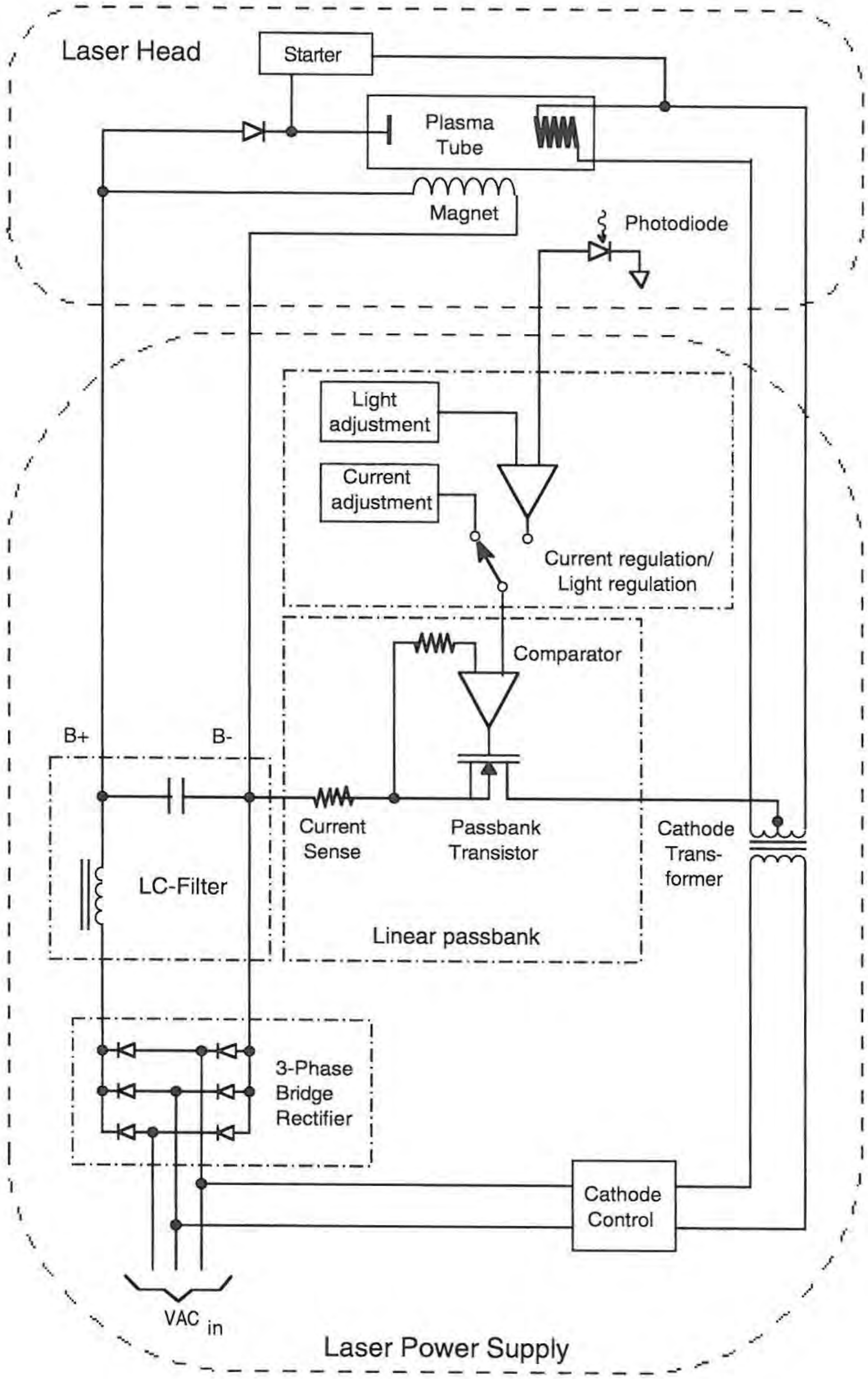


Figure 10-12. Simplified Laser Diagram

Operator's Manual

Chapter Eleven
External Computer Control

COHERENT®

Introduction

This chapter provides details on how to interface the Sabre ion laser with a remote computer. Three different interface protocols are available through the appropriate connectors on the rear of the power supply: the standard RS-232/422 and the optional IEEE-488.

The RS-232/422 and IEEE-488 interfaces are based on a set of laser control instructions, consisting of commands that affect laser operation, and queries that request the laser to return status information to the host. The instruction set is sufficient to support user-written programs that emulate the functions of the Sabre remote control module.

The autofill circuitry will only engage if the system is operating at the same current setting for five minutes. If your application requires frequent changes in current, run the system at full current for fifteen minutes at least once per day. This full current run will allow the autofill circuitry to bring the plasma tube to the correct pressure for tube operation.

Failure to maintain correct tube gas pressure will cause an under voltage fault which will shut down the system. In addition, running the plasma tube at lower than normal gas pressure for prolonged periods is harmful to the tube.

RS-232/422 Interface Connection

The Sabre ion laser supports both RS-232 and RS-422 serial communication through the port on the rear of the power supply. The RS-232/422 port configuration is described in Table 11-1.

In RS-232 communication, the Sabre is configured as a DCE device using only pins 2 (serial data in), 3 (serial data out) and 7 (signal ground). Handshake lines RTS, CTS, DTR and DSR (pins 4, 5, 20 and 6) are not used by the Sabre. Refer to Figure 11-1 or to the Glossary for a definition of terms. To defeat any handshaking requirements of the computer host, RTS is connected to CTS and DTR is connected to DSR inside the Sabre power supply. The node of each pair is tied to a +5 Vdc supply through its own pull-up resistor. The DCD and RI lines (pins 8 and 22) have no connections inside the Sabre power supply.

The connection cable requirements for RS-232 communication are shown in Figure 11-1. For typical PC serial ports; a DB-25

serial port will require a DB-25 to DB-25 wired-straight-through cable, a DB-9 serial port will require a DB-9 to DB-25 modem cable. For typical Macintosh computers, the modem port will require an 8 pin Mini-DIN to DB-25 modem cable. Check the computer's manual to ensure proper cable selection.

In RS-422 communication, the Sabre uses only pins 9 and 11 (serial data in + and -), pins 18 and 25 (serial data out + and -), and pin 7 (signal ground). The handshake lines are configured as described above. The typical cable requirement is shown in Figure 11-1. Check the computer's manual to ensure proper cable selection.

Port Configuration

Table 11-1. RS-232/422 Description

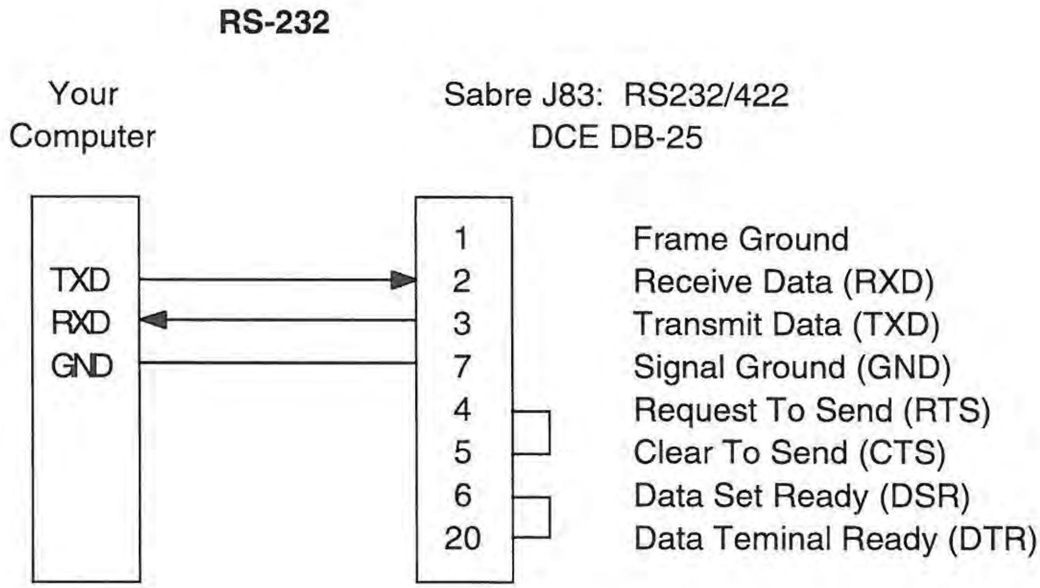
Configuration	DCE, no handshaking
Data bits	8
Stop bits	1
Parity	none
Baud rate	User selectable: 110 300 1200 (factory setting) 4800 9600 19200
Handshake connections inside power supply	RTS to CTS, DTR to DSR: each node pulled up to +5 Vdc. DCD and RI: no connection

Setting the Baud Rate

The baud rate can be adjusted through the remote control module or by means of the Baudrate = n command described in Table 11-4. After the baud rate is changed , the new setting will be stored in system memory. The current baud rate may be queried using the Print Baudrate query described in Table 11-5.

To set the baud rate using the remote control module:

1. Enable access to the Extended Menus by setting switch 8 on the My Talk Address DIP switch on the rear panel of the power supply to the up (on) position.



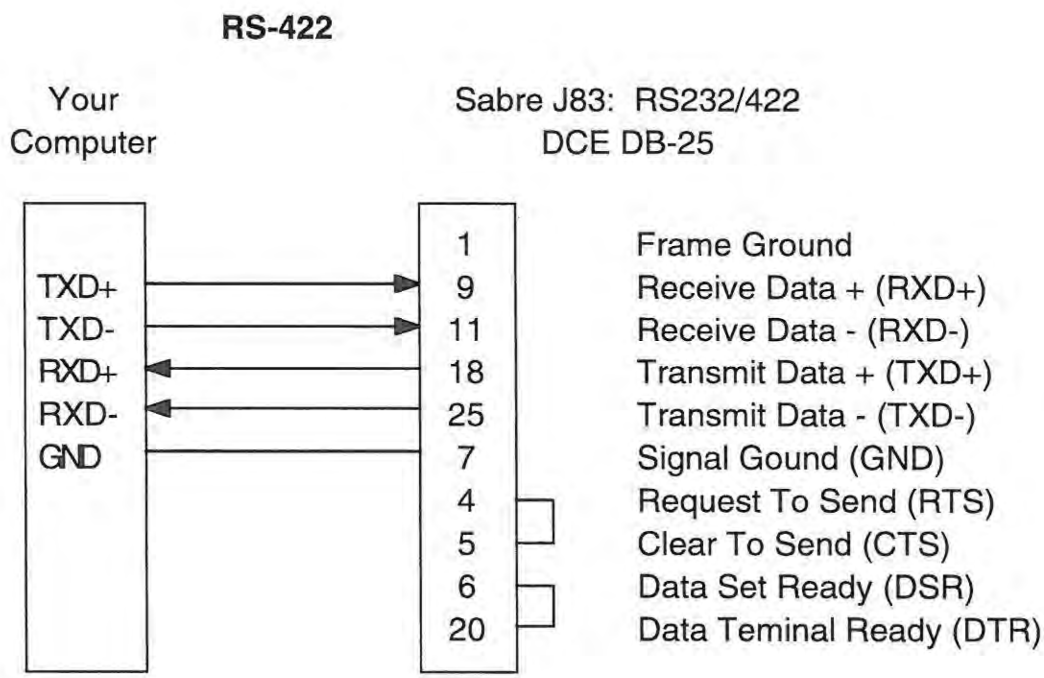


Figure 11-1. RS-232/RS-422 Pin Configurations

Refer to the remote control module menu tree to assist in setting the baud rate.

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2. Use the remote control module to enter the Extended Menu options as you would other menus. Scroll through the Extended Menu options to the "Setup Menu" and press Select.

3. Scroll through the Setup options to the "Baud rate Menu" and press Select.

4. Scroll through the Baud rate parameter options to the desired value and press Select.

5. Set switch 8 on the My Talk Address DIP Switch panel to the down (off) position if Extended Menu operation is no longer desired.

To set the baud rate by the remote computer, send the Baudrate=n command to the laser at the currently set baud rate. After sending this baud rate command, you must reinitialize the remote computer communications port to the new baud rate. The factory set baud rate is 1200.

IEEE-488 OPERATION

When installed as an option, the Sabre ion laser supports IEEE-488 parallel communication through the port on the rear of the power supply. The laser system can be controlled by using the interface commands described in RS-232/422 and IEEE-488 communications instruction set (Tables 11-4 and 11-5).

The IEEE-488 bus is a byte parallel interface bus (refer to: ANSI/IEEE Std. 488-1978, IEEE Standard Digital Interface for Programmable Instrumentation and IEEE Std. 7281982, IEEE Recommended Practice for Code and Format Conventions).

Each device on the IEEE-488 bus has a unique talk/listen address. The Sabre ion laser addresses, My Listen Address (MLA) and My Talk Address (MTA), are determined by the first five switches of the My Talk Address DIP switch (0=off=down, 1=on=up) as shown in Table 11-2.

Table 11-2. My Talk Address DIP Switches

SW5	SW4	SW3	SW2	SW1	Addresses
0	0	0	0	0	MLA, MTA = 0
0	0	0	0	1	MLA, MTA = 1
0	0	0	1	0	MLA, MTA = 2
0	0	0	1	1	MLA, MTA = 3
0	0	1	0	0	MLA, MTA = 4
		• • •		• • •	
1	1	1	0	1	MLA, MTA = 29
1	1	1	1	0	MLA, MTA = 30

IEEE-488 ECHO Mode

The Sabre provides an echo mode as described in a subsequent section. Although a mode with the echo set on may be used in IEEE-488 communications, it is not recommended. As the IEEE-488 interface operates in a handshake mode, turning echo on will complicate data reception without adding value. Communications problems can be detected easily by monitoring bus status variables. The output buffer of the laser system may be cleared by sending the IEEE-488 Device Clear command. The sub-programs and macros necessary for read/write operations, monitoring bus status variables, etc., are usually supplied by the manufacturer of the IEEE-488 computer interface board.

RS-232/422 AND IEEE-488 COMMAND LANGUAGE

Communications Instruction Syntax

Communication with the Sabre is by two types of instructions: commands and queries. Commands set the values of laser operating parameters and queries request the laser to return the values of operating parameters.

Any instruction to the laser consists of a command or query written as a string of ASCII characters and followed by a carriage return and linefeed (<CR><LF>).

For example:

PT=1<CR><LF>

turns PowerTrack on.

PRINT LIGHT<CR><LF>

requests the laser to return the measured laser output power.

The strings input to Sabre are case insensitive. The maximum input string length is 59 characters plus the <CR><LF>. Extra spaces may be added before or after an instruction or between words, the equal sign, or value parameter within the instruction as long as the maximum string length is not exceeded. Only one instruction is allowed per string.

All numeric values returned in responses to queries are represented as strings of ASCII characters. The absolute maximum returned string length is 256 characters plus the <CR><LF>. In Table 11-5, "Print" can be replaced by "?" for all queries. At least one space is required between "Print" and the query. No spaces are required between a "?" and the query.

All of the commands and queries given in Tables 11-4 and 11-5 may be abbreviated by at least the first two characters of each word of a given instruction. Exceptions include some words within instructions which may require more than two characters to distinguish themselves. For example, the shortest string allowed to abbreviate "Temperature" is "Temp" which distinguishes itself from "TEMOO"

For example:

Current = 55.1<CR><LF>

may be abbreviated as

cu = 55.1<CR><LF>

whereas,

Print Set Etalon Temperature<CR><LF>

may be abbreviated with the shortest possible strings as

?Set Et Temp<CR><LF>

Interface Protocol

The Sabre ion laser will always respond to an instruction by returning at least a carriage return and linefeed. In order to keep communication between computer and laser synchronized, it is essential to read the message returned by the laser. Do not send another instruction until a <CR><LF> has been received from the laser. If the message is not retrieved, it will stay in the output buffer of the laser system

until the next time the laser is addressed as talker. Any characters transmitted to the laser during execution of a command may be ignored.

ECHO Mode

The Sabre provides an echo mode in which each character transmitted to the laser is echoed (or immediately returned) to the computer host. This feature can be turned on or off using the ECHO command (refer to Table 11-4). A change in echo mode will take effect with the first command sent after the echo command. The Sabre ion laser will answer each instruction with a message as described in Table 11-3.

INSTRUCTION SET

Table 11-4 describes the commands and Table 11-5 describes the queries for use in RS232/422 and IEEE-488 communication with the Sabre. Table 11-6 is included as a reference table of ASCII characters. The reference numbers listed are keyed to the remote control module menu tree shown on Figure 11-2.

Table 11-3. Response from Laser after Receiving Instruction

Instruction Sent to Laser	Response from Laser	
	ECHO Off	ECHO On
Command<CR><LF>	<CR><LF>	Command<CR><LF>
Query<CR><LF>	Data(1)<CR><LF>	Query + Data(1)<CR><LF>
(Command or Query) <CR><LF> (illegal instruction)	**Syntax Error:** + (Command or Query)<CR><LF>	(Command or Query) + **Syntax Error:** + (Command or Query)<CR><LF>
Command<CR><LF> (illegal operand)	**Out of Range**<CR><LF>	Command + **Out of Range** <CR><LF>
Command<CR><LF> (particular command will not be executed while system ionized)	**Laser must be OFF** <CR><LF>	Command + **Laser must be OFF**<CR><LF>
Command<CR><LF> (particular command will not be executed while main contactor de-energized)	**Laser must be ON**<CR><LF>	Command + **Laser must be ON**<CR><LF>
Command<CR><LF> (particular command will not be executed while rear motors moving)	**Motor Moving**<CR><LF>	Command + **Motor Moving** <CR><LF>
Command<CR><LF> (particular command will not be executed while aperture moving)	**Aperture Moving**<CR><LF>	Command + **Aperture Moving**<CR><LF>
Command<CR><LF> (particular command was sent for an automatic option not installed)	**Not Installed**<CR><LF>	Command + **Not Installed**<CR><LF>
Command<CR><LF> (command string greater than 59 characters)	**Input Too Long**<CR><LF>	**Input Too Long**<CR><LF>

[1] Multiple items will be separated by the & character. For example, a list of system faults will be returned as Low Water Flow&H/E Low Reservoir&Head Interlock.

Table 11-4. Communications Instruction Set – Commands

REF #	COMMANDS	ACTION PERFORMED
1	Echo= n	If n is 0: turn off echo. Characters transmitted to the laser will not be echoed to the host. If n is 1: turn on echo. Characters transmitted to the laser will be echoed to the host. A change in echo mode will take effect with the first command sent after the echo command.
2	Laser= n	If n = 0: de-ionize tube and de-energize the power supply main contactor. If n = 1: start heat exchanger and initiate start sequence which will energize the cathode and power supply main contactor, and ionize the tube.
3	Shutter= n	If n = 0: request a closed external shutter. If n = 1: request an open external shutter.
4	PowerTrack= n or PT= n	If n = 0: turn off PowerTrack. If n = 1: turn on PowerTrack. If n = 2: recalibrate PowerTrack. This command will execute only if PowerTrack is on and light regulation is off. If n = 3: center PowerTrack and turn it off. During movement of the aperture or rear motors, this command will not be executed and the response from the system will be "Aperture Moving" or "Motor Moving".
5	Current= nn.nn	Set to Current Regulation Mode at the specified current.
6	Light= nn.nnnn or LR= nn.nnnn	Set to Light Regulation Mode at the specified output power.
7	TUNE = n	If n = 0: abort TUNE procedure if in progress. Abort any procedure that moves the rear motors such as changing the wavelength. If n = 1: initiate TUNE procedure. During movement of the aperture or rear motors, this command will not be executed and the response from the system will be "Aperture Moving" or "Motor Moving".
8	Aperture= n	If n = 0: set the aperture to the CLOSED position. If $1 \le n \le 18$: set the aperture to the specified position. Refer to Appendix B for the dimensions of each position. If n = 19: set the aperture to the OPEN position. If n = 20: set the aperture to the position that gives TEM_{00}. If n = 255: abort the aperture move in progress. During movement of the aperture or rear motors, this command will not be executed and the response from the system will be "Aperture Moving" or "Motor Moving". If the aperture is not installed, then this command will not be executed and the response form the system will be "Not Installed".
The REF # column refers to the menu tree located on Figure 11-2.		

Table 11-4. Communications Instruction Set – Commands (Continued)

REF #	COMMANDS	ACTION PERFORMED
9	Wavelength = n	Set wavelength to a value from the following list if the appropriate optics set is installed and selected. Wavelengths are in nm. For argon: n = 275.4, 300.3, 302.4, 305.5, 333.6, 334.5, 335.8, 351.1, 363.8, 379.5, 385.8, 454.5, 457.9, 465.8, 472.7, 476.5, 488.0, 496.5, 501.7, 514.5, 528.7, MLVIS, MLUV, MLDUV, MLSUV, or MLLUV. For krypton: n = 337.5, 350.7, 356.4, 406.7, 413.1, 415.4, 468.0, 476.2, 482.5, 520.8, 530.9, 568.2, 647.1, 676.4, 752.5, 799.3, MLRED, MLUV, MLVI, MLBG, MLYG, MLIR. During movement of the aperture or rear motors, this command will not be executed and the response from the system will be "Aperture Moving" or "Motor Moving". If the rear motors are not installed, this command will set the wavelength for proper power calibration.
10	Optic Set = n	Set the present optic set to the specified value. For argon: If n = 1: 275.4 nm only. If n = 2: 275.4 - 305.5 nm, MLDUV. If n = 3: 300.3 - 335.8 nm, MLSUV. If n = 4: 333.6 - 363.8 nm, MLUV. If n = 5: 351.1 - 385.8 nm, MLLUV. If n = 6: 454.5 nm only. If n = 7: 454.5 - 514.5 nm, MLVIS. If n = 8: 528.7 nm only. For krypton: If n = 1: 337.5 - 356.4 nm, MLUV. If n = 2: 406.7 - 415.4 nm, MLVI. If n = 3: 468.0 - 530.9 nm, MLBG. If n = 4: 520.8 - 568.2 nm, MLYG. If n = 5: 647.1 - 676.4 nm, MLRED. If n = 6: 752.5 - 799.3 nm, MLIR. Only effective if used before setting the wavelength. If a given wavelength is a member of more than one of the software-recognized installed optic sets, this command must be used to eliminate ambiguity as to which optic set is physically installed in the laser head.

The REF # column refers to the menu tree located on Figure 11-2.

Table 11-4. Communications Instruction Set – Commands (Continued)

REF #	COMMANDS	ACTION PERFORMED
11	Etalon Mode= n or Emode= n	If n is 0: put etalon in manual temperature mode with no change in the set temperature. If n = 1: start ModeTrack. If n = 2: start ModeTune. If n = 3: start ModeFineTune. If n = 4: start NuTrack.
12	Etalon Temperature= nn.nnn or Etalon= nn.nnn	Set the etalon temperature in degrees Centigrade. The allowed temperature range is 51.500 to 56.500° C.
13	ZDAC = n	Set the cavity length Z-axis DAC to the specified value. $300 \leq n \leq 3796$. Note: Valid ZDAC range is dependent on PowerTrack DAC values. During movement of the aperture or rear motors, this command will not be executed and the response from the system will be "Aperture Moving" or "Motor Moving".
14	Store Memory n	Store the present settings of regulation mode, set current or set light, wavelength, PowerTrack on or off, and aperture position (0 to 19) as memory level n. $0 \leq n \leq 9$. Storing in n = 1 or 2 changes the corresponding levels available for recall on the remote control module. During movement of the aperture or rear motors, this command will not be executed and the response from the system will be "Aperture Moving" or "Motor Moving".
15	Recall Memory n	Recall the stored memory level n containing settings for regulation mode, set current or set light, wavelength, PowerTrack on or off, and aperture position (0 to 19). $0 \leq n \leq 9$. Recalling levels n = 1 or 2 correspond to those levels that can be set on the remote control module. During movement of the aperture or rear motors, this command will not be executed and the response from the system will be "Aperture Moving" or "Motor Moving".
16	Field = n	Set the magnetic field (on krypton Sabre only). If n = 0: set to low field. If n = 1: set to high field. This command will not be executed if the laser is ionized or in start delay where the response from the system will be "Laser must be OFF".
The REF # column refers to the menu tree located on Figure 11-2.		

Table 11-4. Communications Instruction Set – Commands (Continued)

REF #	COMMANDS	ACTION PERFORMED
17	Water= n	Set the manual heat exchanger control. If n = 0: set manual heat exchanger control to off. If the system is deionized, the heat exchanger will shut off in 5 minutes. If n = 1: set manual heat exchanger control to on. Used to turn on heat exchanger when laser is deionized. Heat exchanger will stay on indefinitely, unless laser is started then shut off or WATER=0 command is used. To determine if heat exchanger is operating, use the query, PRINT WATER FLOW.
18	PTDACA= n PTDACB= n	Set the PowerTrack DAC A (vertical) or B (horizontal) setpoint to the specified value. $0 \leq n \leq 255$. During movement of the aperture or rear motors, this command will not be executed and the response from the system will be "Aperture Moving" or "Motor Moving". This command will not be executed if PowerTrack is on where the response from the system will be "Motor Moving".
19	Photocell Monitor = n	If n = 0: disable photocell automatic gain switching (default during light regulation). If n = 1: enable photocell automatic gain switching (default during current regulation).
20	Photocell Gain = n	Set the photocell gain to the specified value. n = 1, 2, 4, 8, 16, 32, 64, 128, 256, 512. This command will execute only if PHOTOCELL MONITOR = 0.
21	Horizontal Steps = n	Move rear mirror plate horizontal stepper motor n steps. $\lvert n \rvert \leq 60{,}000$. This command can corrupt system calibration and should only be used by qualified personnel.
22	Vertical Steps = n	Move rear mirror plate vertical stepper motor n steps. $\lvert n \rvert \leq 60{,}000$. This command can corrupt system calibration and should only be used by qualified personnel.
The REF # column refers to the menu tree located on Figure 11-2.		

Table 11-4. Communications Instruction Set – Commands (Continued)

REF #	COMMANDS	ACTION PERFORMED
23	Motor Home = n	Move rear mirror plate to a known calibrated position. For argon: If n = 0: move to multiline position. If n = 1: move to visible crossover position. If n = 2: move to UV crossover position. If n = 3: move to D/SUV crossover position. For krypton: If n = 0: move to multiline position. If n = 1: move to VIS/IR crossover position. If n = 2: move to UV crossover position. This command can corrupt system calibration and should only be used by qualified personnel.
24	Search = n	Perform a localized rear mirror plate search to establish and optimize lasing without going to the home position. If n = 0: abort search. If n = 1: initiate search. This command can corrupt system calibration and should only be used by qualified personnel.
25	Aperture Steps = n	Move automatic aperture stepper motor n steps. $\lvert n \rvert \leq 60{,}000$. This command can corrupt system calibration and should only be used by qualified personnel.
26	Baudrate= n	Set the RS-232/422 baud rate to the specified value. n= 110, 300, 1200, 2400, 4800, 9600, 19200.
27	AutoLTCal= n	If n = 0: turn automatic light regulation calibration off. If n = 1: turn automatic light regulation calibration on (default at installation).
The REF # column refers to the menu tree located on Figure 11-2.		

Table 11-4. Communications Instruction Set – Commands (Continued)

REF #	COMMANDS	ACTION PERFORMED
28	PctChgTilRecal= n	This command changes the allowed percent current change before recalibration becomes necessary in light regulation (see also command AUTOLTCAL and Chapter Five, System Description and Control). The default setting for this limit is 20%. $5 \leq n \leq 100$. This command should be used only in the linear power versus current range of any laser line. A frequently used application for this command is ramping the laser power. This is accomplished by disabling automatic recalibration after entering light regulation mode at the highest desired power level and setting PctChgTilRecal to the value corresponding to the linear power versus current range of that laser line. Now the power can be changed over this range with maximum resolution and linearity in standard light regulation mode with PowerTrack engaged. PctChgTilRecal will return to the default setting each time the laser is started.
29	Auto Shutter = n	Set the status of automatic shutter close for TUNE, initiation of start delay sequence, wavelength move, or aperture move. If n= 0: disabled. If n = 1: enabled.
30	Exposure = n.n	Start an exposure time for the external shutter to be open. If the shutter is closed, the shutter will open for n.n seconds and then close. If the shutter is open, the shutter will close in n.n seconds. To override this command, use EXPOSURE = 0 or SHUTTER = 0 or 1. $0.1 \leq n \leq 3250.0$ seconds.
31	Cal Set Light	Calibrate the light regulation setpoint DAC to the photocell power reading. This command involves a calibration procedure and should only be used by qualified personnel. This command will only be executed if the system is in the Light Regulation Mode.
32	Cal Photocell = nn.nnnn	Calibrate the photocell light reading at the present wavelength to the power nn.nnnn. This command involves a calibration procedure and should only be used by qualified personnel.
33	PowerTrack Installed = n or PT Installed = n	If n = 0: de-install the PowerTrack option. If n = 1: install the PowerTrack option.
34	Aperture Installed = n	If n = 0: de-install the automatic aperture option. If n = 1: install the automatic aperture option.
35	Motors Installed = n	If n = 0: de-install the automatic rear motors option. If n = 1: install the automatic rear motors option.
The REF # column refers to the menu tree located on Figure 11-2.		

Table 11-4. Communications Instruction Set – Commands (Continued)

REF #	COMMANDS	ACTION PERFORMED
36	Cal Autofill = n	If n = 0: cancel autofill calibration procedure if in progress. If n = 1: initiate autofill calibration procedure. This command involves a calibration procedure and should only be used by qualified personnel.
37	NoFill Range = n	Changes the minimum current at which autofill will be operable. The power on default is 20A. $20 \le n \le$ Max Current.
38	Next Wavelength = n	If n = 0: move the rear motors to the next lower wavelength found. If n = 1: move the rear motors to the next higher wavelength found. This moves the vertical motor only and may not set the lasing wavelength to the wavelength displayed for the photocell calibration. It should only be used by qualified personnel during calibration or as a troubleshooting aid. During movement of the aperture or rear motors, this command will not be executed and the response from the system will be "Aperture Moving" or "Motor Moving".
39	Installed Optics = n	Calibrate a number, n, corresponding to the optic sets available. The number represents a summation of avaliable installable optic sets shown below. For argon: 1 = Optic Set 1: 275.4 nm only. 2 = Optic Set 2: 275.4 - 305.5 nm, MLDUV. 4 = Optic Set 3: 300.3 - 335.8 nm, MLSUV. 8 = Optic Set 4: 333.6 - 363.8 nm, MLUV. 16 = Optic Set 5: 351.1 - 385.8 nm, MLLUV. 32 = Optic Set 6: 454.5 nm only. 64 = Optic Set 7: 454.5 - 514.5 nm, MLVIS. 128 = Optic Set 8: 528.7 nm only. For krypton: 1 = Optic Set 1: 337.5 - 356.4 nm, MLUV. 2 = Optic Set 2: 406.7 - 415.4 nm, MLVI. 4 = Optic Set 3: 468.0 - 530.9 nm, MLBG. 8 = Optic Set 4: 520.8 - 568.2 nm, MLYG. 16 = Optic Set 5: 647.1 - 676.4 nm, MLRED. 32 = Optic Set 6: 752.5 - 799.3 nm, MLIR. For example, INSTALLED OPTICS = 72, installs optic sets 4 and 7 for argon.
The REF # column refers to the menu tree located on Figure 11-2.		

Table 11-5. Communications Instruction Set – Queries

REF #	QUERIES	RETURNED INFORMATION
100	Print Faults	Return a list of all active faults separated by a & and terminated by a <CR><LF> or return "System OK" if no active faults.
101	Print Laser	Return: 0 if the power supply main contactor is de-energized and the laser is off. 1 if the cathode or main contactor is energized and laser is in start delay (tube not ionized). 2 if the power supply main contactor is energized and the laser is ionized.
102	Print Start	Return the time, nn.n, in seconds remaining in the start delay countdown. The number is zero when not in start delay.
103	Print Shutter	Return the status of the external shutter: 0 if shutter hardware closed and user-requested state closed. 1 if shutter hardware open or if user-requested state open.
104	Print PowerTrack or Print PT or Print PowerTrack Mode or Print PT Mode	Return the status of PowerTrack: 0 if not installed. 1 if off. 2 if parked, on. 3 if on. 4 if out of range, parked. 5 if calibrating.
105	Print Mode	Return the laser operating mode: 0 if in current regulation. 1 if in reduced bandwidth light regulation. 2 if in standard light regulation. 3 if light regulation out of range, in current regulation.
106	Print Current	Return the calibrated tube current, nn.n, in amps.
107	Print Set Current	Return the current regulation set point, nn.nn, in Amps. Note that data returned from this query is only meaningful if the laser system is operating in Current Regulation Mode (refer to PRINT MODE).
108	Print Light	Return the calibrated output power, nn.nnn, in Watts.
109	Print Set Light	Return the light regulation set power, nn.nnnn, in Watts. Note that data returned from this query is only meaningful if the laser system is operating in Current Regulation Mode (refer to PRINT MODE).

- The REF # column refers to the menu tree located on Figure 11-2.
- The single character **?** may be substituted for **Print** in all queries. For example:
  ? SET CURRENT for **PRINT SET CURRENT**

Table 11-5. Communications Instruction Set – Queries (Continued)

REF #	QUERIES	RETURNED INFORMATION
110	Print TUNE	Return the status of the TUNE procedure. 0 if active. 1 if inactive (done).
111	Print Gas	Return the system gas type: 0 if argon. 1 if krypton.
112	Print Tube Hours or Print Hours	Return the number of ionized operating hours on the present plasma tube.
113	Print Head Hours	Return the number of ionized operating hours on the system head.
114	Print Water Flow or Print Flow	Return the water flow rate, n.n, in gallons per minute.
115	Print Water Temperature	Return the power supply inlet water temperature, nn.n, in °C.
116	Print Water Resistivity	Return the power supply inlet water resistivity, nnnn.n, in kΩ • cm.
117	Print Cathode Current	Return the measured cathode current, nn.n, in Amps RMS.
118	Print Magnet Current	Return the magnet current, nn.n, in Amps.
119	Print Autofill Delta	Return the autofill pressure delta, n.n, in Volts.
120	Print Autofill Count	Return the total number of gas fills taken by the plasma tube.
121	Print Autofill Hours or HrsTilShutdown	Return the remaining hours of operation with a negative autofill delta before the system shuts down automatically. Maximum (default) is 100 and is reset whenever delta is positive.
122	Print NoFill Range	Returns the minimum current at which autofill will be operable. The power on default is 20 A.
123	Print Autofill Mode or Print Autofill	Return the autofill calibration status: 0 if not calibrating, no calibration requested. 1 if not calibrating, calibration requested but head was not ready. 2 if not calibrating, calibration done. 3 if not calibrating, calibration requested but was aborted because head CPU reset. 4 if calibrating. 5 if changing the magnetic field during calibration of a Krypton system. 6 if waiting for start delay after a field change during Krypton system calibration.

- The REF # column refers to the menu tree located on Figure 11-2.
- The single character **?** may be substituted for **Print** in all queries. For example:
  ? SET CURRENT for **PRINT SET CURRENT**

Table 11-5. Communications Instruction Set – Queries (Continued)

REF #	QUERIES	RETURNED INFORMATION
124	Print Passbank Voltage	Return the measured passbank voltage, nnn.n, in volts.
125	Print Tube Voltage	Return the measured tube voltage, nnn.n, in volts.
126	Print Aperture	Return the present aperture position. Note: During movement of the aperture, the response from the system to this query will be "Aperture Moving". Note: If the aperture is not installed, then the response from the system to this query will be "Not Installed".
127	Print Aperture Status	Return the status of the automatic aperture: 0 if not moving. 1 if move requested. 2 if moving started. 3 if moving in a home search.
128	Print Aperture Errors	Return one of the following errors encountered during the last move of the automatic aperture: 0 if no errors occurred, aperture was found. 1 if TEM_{00} was requested, but could not be achieved. 2 if position sensor was located and aperture number reset. (Error will appear only momentarily.) 3 if position sensor could not be found.
129	Print TEMoo	Return the mode status of the output beam as measured by the TEM_{00} detector: 0 if output beam is not operating in only one transverse mode, not TEM_{00}. 1 if output beam is operating in only one transverse mode, most probably TEM_{00}. Note: This query requires sending letters oo and not two zeroes.
130	Print Wavelength	Return the present wavelength setting. During movement of the rear motors, the response from the system to this query will be "Motor Moving".
131	Print Motor Status	Return the status of the motors controlling the rear mirror plate: 0 if not moving. 1 if move requested. 2 if moving started. 3 if moving in a home search. 4 if peaking. 5 if searching. 6 if moving to crossover. 7 if moving to Multiline. 8 if moving to reference wavelength. 9 if moving to requested wavelength.

- The REF # column refers to the menu tree located on Figure 11-2.
- The single character **?** may be substituted for **Print** in all queries. For example:
  ? SET CURRENT for **PRINT SET CURRENT**

Table 11-5. Communications Instruction Set – Queries (Continued

REF #	QUERIES	RETURNED INFORMATION
132	Print Wavelength Errors	Return one of the following errors encountered during the last move of the rear motors: 0 if "No Errors": no errors occurred, wavelength was found. 1 if "Other line found": requested wavelength was not found. 2 if "Lasing not found": wavelength was not found 3 if "VERT home not found": vertical home sensor was not detected. 4 if "HORZ home not found": horizontal home sensor was not detected. 5 if "Photocell error": photocell measurement in head invalid
133	Print Optic Set	Return a number, n, corresponding to the present optic set. For argon: If n = 1: 275.4 nm only. If n = 2: 275.4 - 305.5 nm, MLDUV. If n = 3: 300.3 - 335.8 nm, MLSUV. If n = 4: 333.6 - 363.8 nm, MLUV. If n = 5: 351.1 - 385.8 nm, MLLUV. If n = 6: 454.5 nm only. If n = 7: 454.5 - 514.5 nm, MLVIS. If n = 8: 528.7 nm only. For krypton: If n = 1: 337.5 - 356.4 nm, MLUV. If n = 2: 406.7 - 415.4 nm, MLVI. If n = 3: 468.0 - 530.9 nm, MLBG. If n = 4: 520.8 - 568.2 nm, MLYG. If n = 5: 647.1 - 676.4 nm, MLRED. If n = 6: 752.5 - 799.3 nm, MLIR.
134	Print Etalon Mode or Print Emode	Return the etalon mode: 0 if in manual mode. 1 if ModeTrack active. 2 if ModeTune active. 3 if ModeFineTune active. 4 if NuTrack active. Each of the above is multiplied by 10 if an error occurs while running the procedure. The etalon will be in manual mode.
135	Print Set Etalon Temperature or Print Set Etalon	Return the set etalon temperature, nn.nnn, in °C.
136	Print Etalon Temperature or Print Etalon	Return the measured etalon temperature, nn.nnn, in °C.
137	Print ZDAC	Return the present setpoint of the cavity length z-axis DAC.

- The REF # column refers to the menu tree located on Figure 11-2.
- The single character **?** may be substituted for **Print** in all queries. For example:
  ? SET CURRENT for **PRINT SET CURRENT**

Table 11-5. Communications Instruction Set – Queries (Continued

REF #	QUERIES	RETURNED INFORMATION
138	Print Memory n Mode	Return the regulation mode for memory level n: 0 if current regulation. 1 if light regulation. $0 \leq n \leq 9$.
139	Print Memory n Setpoint	Return the current or light power setpoint for memory level n. $0 \leq n \leq 9$.
140	Print Memory n Wavelength	Return the wavelength setting for memory level n. $0 \leq n \leq 9$.
141	Print Memory n PowerTrack or Print Memory n PT	Return the PowerTrack setting for memory level n: 0 if PowerTrack off. 1 if PowerTrack on. $0 \leq n \leq 9$.
142	Print Memory n Aperture	Return the aperture setting (0 to 19) for memory level n. $0 \leq n \leq 9$.
143	Print Field	Return the magnetic field sensed by the system hardware (meaningful on krypton Sabre only): 0 if low field. 1 if high field.
144	Print Set Field	Return the requested magnetic field (meaningful on krypton Sabre only): 0 if low field. 1 if high field.
145	Print Resets	Return the number of power supply CPU resets.
146	Print Head Resets	Return the number of the head CPU resets.
147	Print Software	Return the version number of the power supply software.
148	Print Head Software	Return the version number of the head software.
149	Print Head Sends	Return the number of commands sent by the power supply to the head.
150	Print Head Retries	Return the number of retries for commands sent by the power supply to the head.
151	Print Head Errors	Return the number of errors for commands sent by the power supply to the head. An error occurs after 3 retries, of the same command, fail.
152	Print Head Sync	Return the number of synchronization errors encountered with the head and power supply communication. This error occurs when a head response does not correspond properly to the command sent by the power supply.
153	Print Head Message	Return the last text status message sent by the head to the power supply.

- The REF # column refers to the menu tree located on Figure 11-2.
- The single character **?** may be substituted for **Print** in all queries. For example:
  ? SET CURRENT for **PRINT SET CURRENT**

Table 11-5. Communications Instruction Set – Queries (Continued

REF #	QUERIES	RETURNED INFORMATION
154	Print Remote Sends	Return the number of asynchronous status change messages sent by the power supply to the remote.
155	Print Remote Retries	Return the number of retries for asynchronous status change messages sent by the power supply to the remote.
156	Print Remote Errors	Return the number of errors for asynchronous status change messages sent by the power supply to the remote. An error occurs after 2 retries, of the same message, fail.
157	Print Remote Send Errors	Return the number of erroneous commands received by the power supply (that were sent by the remote). An erroneous command is any command that is invalid and unusable by the power supply.
158	Print Raw Cathode Current	Return the raw (uncalibrated) value of the measured cathode current, nn.n, in Amps RMS.
159	Print Cathode Voltage	Return the measured cathode voltage, n.nn, in Volts RMS.
160	Print Cathode Setpoint	Return the value of the cathode setpoint.
161	Print Cathode Set Voltage	Return the set cathode voltage, n.nnn, in Volts RMS.
162	Print Fan	Return a relative value of the power supply fan speed.
163	Print Noise or Print RMS	Return the measured optical RMS noise, n.nnn, in percent.
164	Print Positive Voltage	Return the measured voltage, nn.nn, of the +12 V supply on the power supply controller PCB.
165	Print Negative Voltage	Return the measured voltage, -nn.nn, of the -12 V supply on the power supply controller PCB.
166	Print Head Positive Voltage	Return the measured voltage, nn.nn, of the +12 V supply on the head PCB.
167	Print Head Negative Voltage	Return the measured voltage, -nn.nn, of the -12 V supply on the head PCB.
168	Print Ripple Current	Return the ripple current, nn.n, in Amps supplied by the power supply's filter capacitors to suppress line noise.
169	Print Maximum Ripple Current	Return the maximum ripple current detected, nn.n, in Amps supplied by the power supply's filter capacitors to suppress line noise.
170	Print Water	Return the status of the manual heat exchanger control: 0 if off. 1 if on.
171	Print PT Gain	Return the present PowerTrack gain.
172	Print Maximum PT Gain	Return the maximum PowerTrack gain.
173	Print PT Filter	Return the present PowerTrack filter which reflects the amplitude of the PowerTrack error signal.

- The REF # column refers to the menu tree located on Figure 11-2.
- The single character **?** may be substituted for **Print** in all queries. For example:
  ? SET CURRENT for **PRINT SET CURRENT**

Table 11-5. Communications Instruction Set – Queries (Continued

REF #	QUERIES	RETURNED INFORMATION
174	Print PTDACA Print PTDACB	Return the measured DAC reading of the PowerTrack DAC for A (vertical) and B (horizontal). The range of values is between 0 and 1023.
175	Print Set PTDACA Print Set PTDACB	Return the present setpoint of the PowerTrack DAC for A (vertical) and B (horizontal). The range of values is between 0 and 255.
176	Print Photocell n	Return photocell values at three points between the photocell and the power supply microprocessor. n = 1 : just before microprocessor input on power supply controller PCB. n = 2: just after input to power supply controller PCB. n = 3: just before output from head PCB.
177	Print Photocell Temperature	Return the photocell temperature, nn.nnn, in °C.
178	Print Photocell Monitor	Return the status of the photocell automatic gain switching: 0 if disabled (default during light regulation). 1 if enabled (default during current regulation).
179	Print Photocell Gain	Return the gain setting of the photocell amplifiers in the head.
180	Print LR Errors	Return a decimal value of the light regulation (LR) error bits displayed by the remote. The number represents a summation of the errors shown below. 1 = Inner Loop Error: hardware error of LR control circuit. 2 = Bad LR Setting Error: software LR setup error. 4 = Scale Factor Error: bad or non-existent photocell or set light DAC calibration for present wavelength. 8 = No Head Response Error: head communication did not acknowledge requested photocell gain. 16 = Not Converging Error: LR calibration algorithm cannot converge to proper gain setting for standard light regulation. 32 = Low Gain Error: LR calibration algorithm cannot set to high enough gain setting for standard light regulation because power vs. current gain is too low for this wavelength at this current. 64 = Excess Gain Error: LR calibration algorithm cannot set to low enough gain setting for standard light regulation because power vs. current gain is too high for this wavelength at this current. 128 = Open Loop Error: hardware error of LR control circuit, LR calibration could not measure 2 kHz calibration signal.
181	Print LR Setpoint	Return the decimal value of the light regulation DAC setpoint for the present power.
182	Print LR Gain	Return the decimal value of the light regulation gain.
183	Print Baudrate	Return the present RS-232/422 baud rate.

- The REF # column refers to the menu tree located on Figure 11-2.
- The single character **?** may be substituted for **Print** in all queries. For example:
  ? SET CURRENT for **PRINT SET CURRENT**

Table 11-5. Communications Instruction Set – Queries (Continued)

REF #	QUERIES	RETURNED INFORMATION
184	Print AutoLTCal	Return the status of automatic light calibration: 0 if disabled. 1 if enabled.
185	Print PctChgTilRecal	This command returns the percent current change before recalibration becomes necessary during light regulation (see also command AUTOLTCAL and Chapter Five, System Description and Control). The default setting at power on is 20%.
186	Print Auto Shutter	Return the status of automatic shutter close for TUNE, initiation of start delay sequence, wavelength move, or aperture move: 0 if disabled. 1 if enabled.
187	Print Maximum Current	Return the maximum power supply current.
188	Print Aperture Installed	Return the auto aperture option status: 0 if not installed. 1 if installed.
189	Print Motors Installed	Return the automatic rear motors option status: 0 if not installed. 1 if installed.
190	Print Minimum Current	Return the minimum power supply current.
191	Print Maximum Tube Current	Return the maximum tube current.

- The REF # column refers to the menu tree located on Figure 11-2.
- The single character **?** may be substituted for **Print** in all queries. For example:
  ? SET CURRENT for **PRINT SET CURRENT**

Table 11-5. Communications Instruction Set – Queries (Continued)

REF #	QUERIES	RETURNED INFORMATION
192	Print Installed Optics	Return a number, n, corresponding to the optic sets available. The number represents a summation of avaliable installable optic sets shown below. For argon: 1 = Optic Set 1: 275.4 nm only. 2 = Optic Set 2: 275.4 - 305.5 nm, MLDUV. 4 = Optic Set 3: 300.3 - 335.8 nm, MLSUV. 8 = Optic Set 4: 333.6 - 363.8 nm, MLUV. 16 = Optic Set 5: 351.1 - 385.8 nm, MLLUV. 32 = Optic Set 6: 454.5 nm only. 64 = Optic Set 7: 454.5 - 514.5 nm, MLVIS. 128 = Optic Set 8: 528.7 nm only. For krypton: 1 = Optic Set 1: 337.5 - 356.4 nm, MLUV. 2 = Optic Set 2: 406.7 - 415.4 nm, MLVI. 4 = Optic Set 3: 468.0 - 530.9 nm, MLBG. 8 = Optic Set 4: 520.8 - 568.2 nm, MLYG. 16 = Optic Set 5: 647.1 - 676.4 nm, MLRED. 32 = Optic Set 6: 752.5 - 799.3 nm, MLIR. For example, if PRINT INSTALLED OPTICS returns the number, 72, for argon, optic sets 4 and 7 are installed.
193	Print Extended	Return status remote extended menus switch on rear of power supply: 0 if OFF, extended menus not active. 1 if ON, extended menus active.
194	Print ID	Returns "SABRE".

- The REF # column refers to the menu tree located on Figure 11-2.
- The single character **?** may be substituted for **Print** in all queries. For example:

  ? SET CURRENT for **PRINT SET CURRENT**

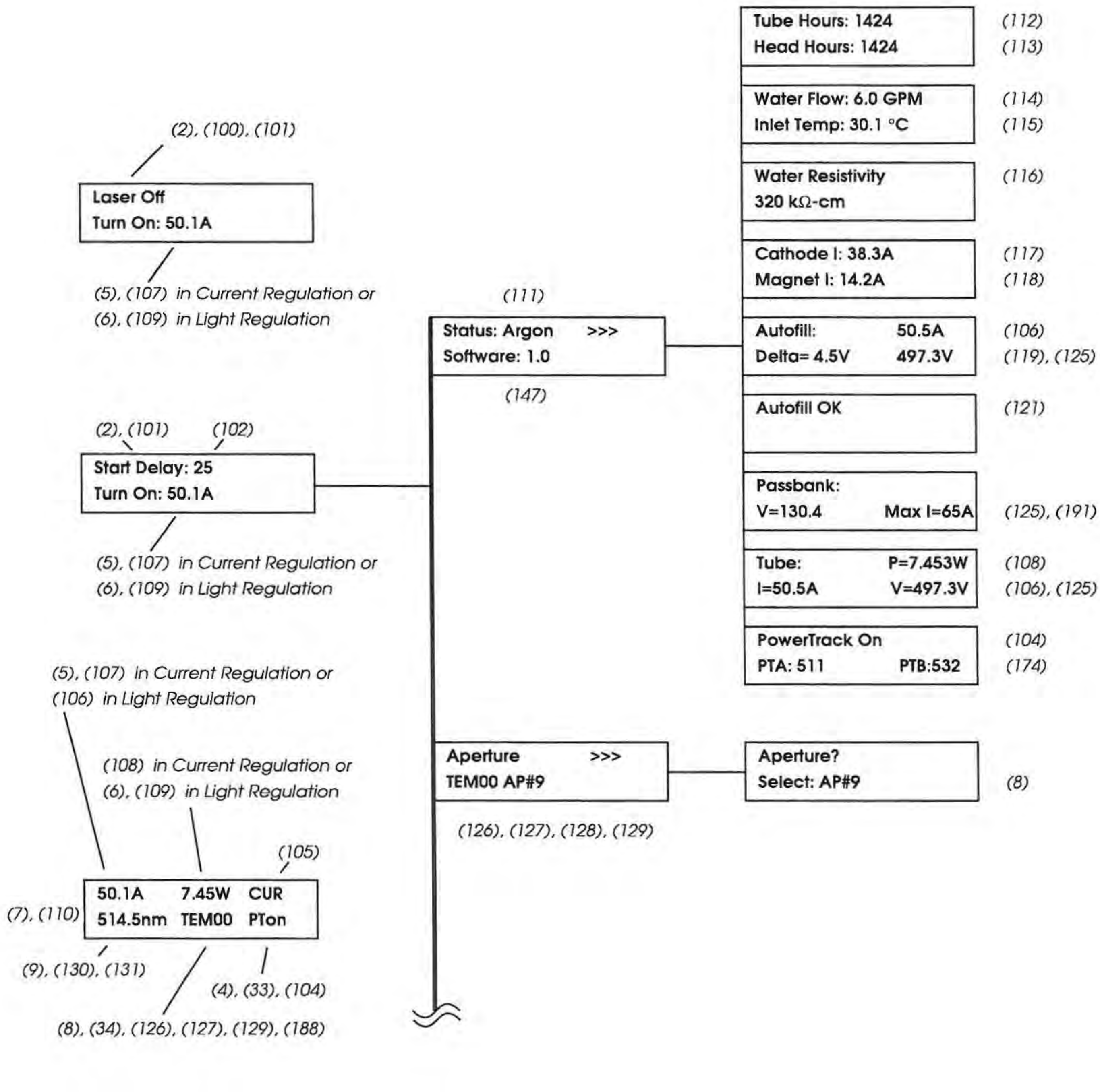

Figure 11-2a. Sabre Menu Tree, Standard Menus (Sheet 1 of 5)

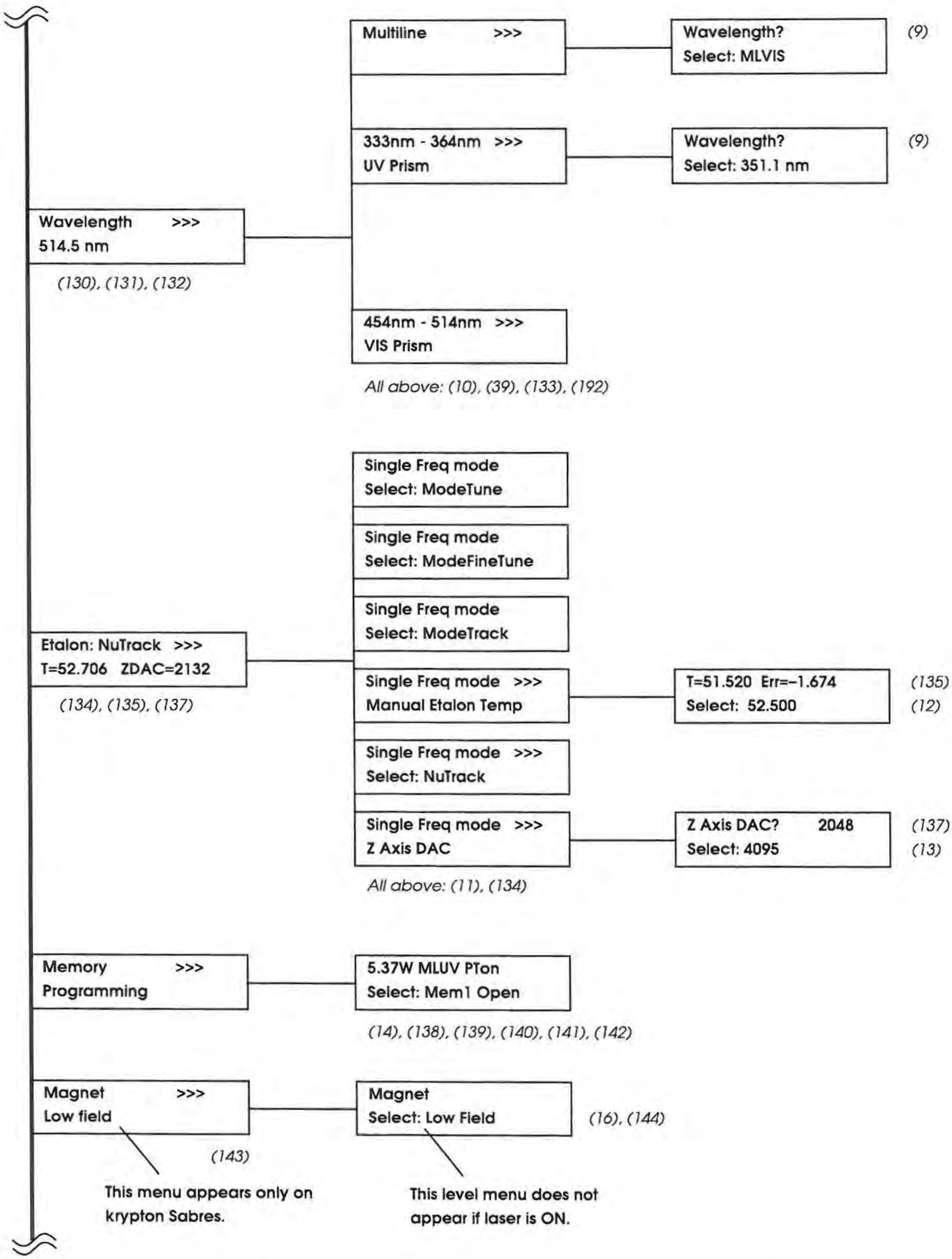

Figure 11-2a. Sabre Menu Tree, Standard Menus (Sheet 2 of 5)

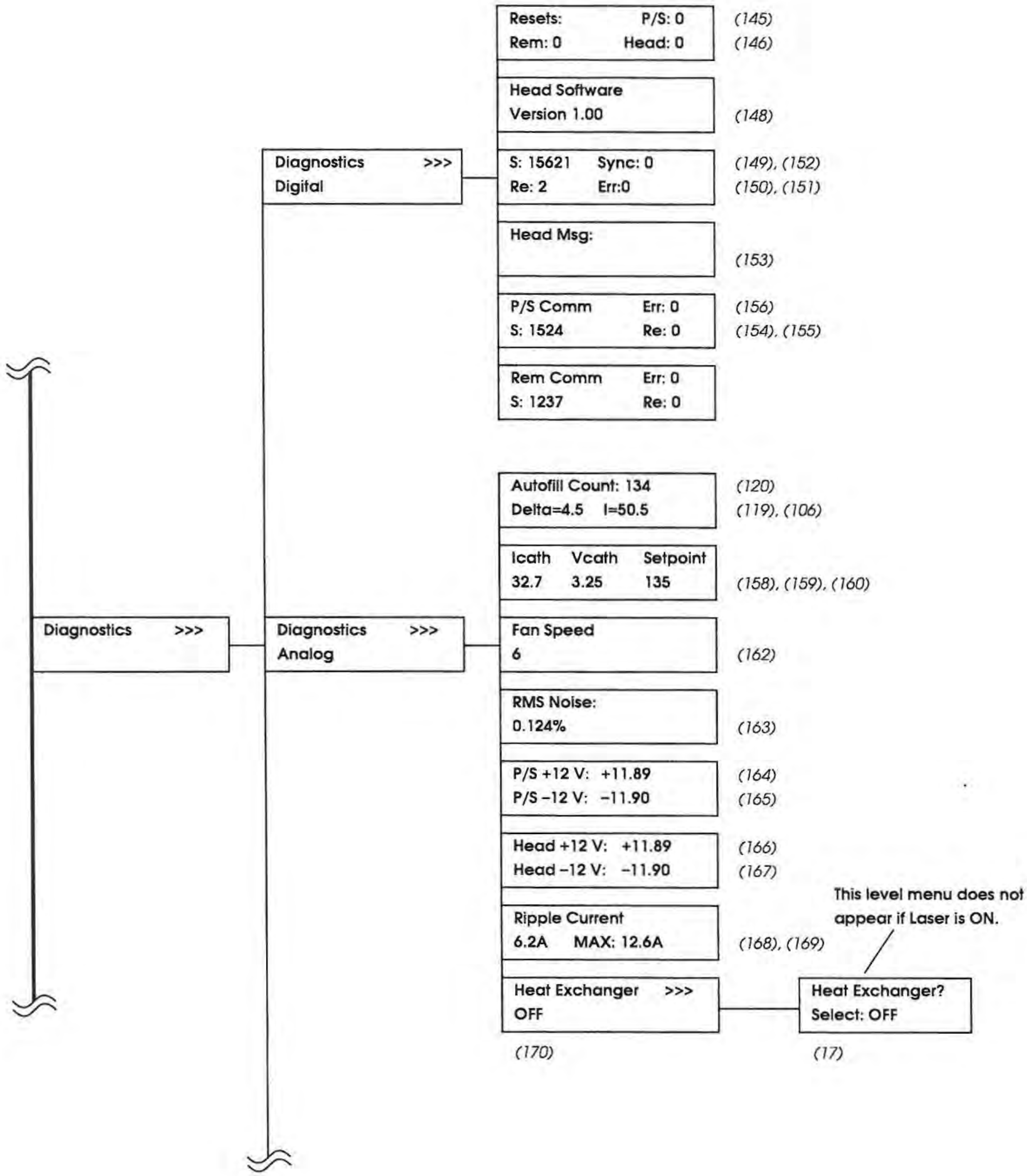

Figure 11-2b. Sabre Menu Tree, Extended Menus (Sheet 3 of 5)

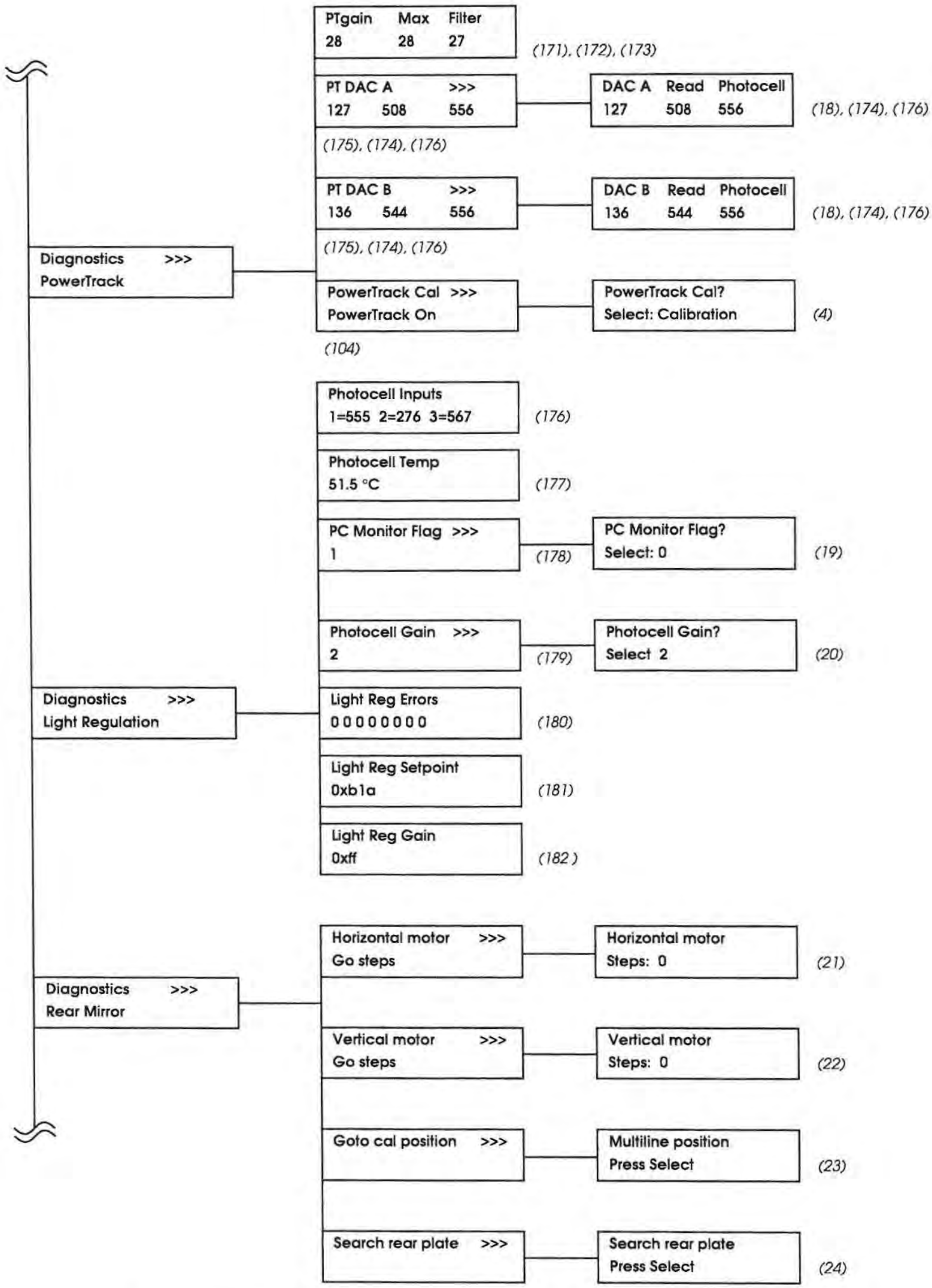

Figure 11-2b. Sabre Menu Tree, Extended Menus (Sheet 4 of 5)

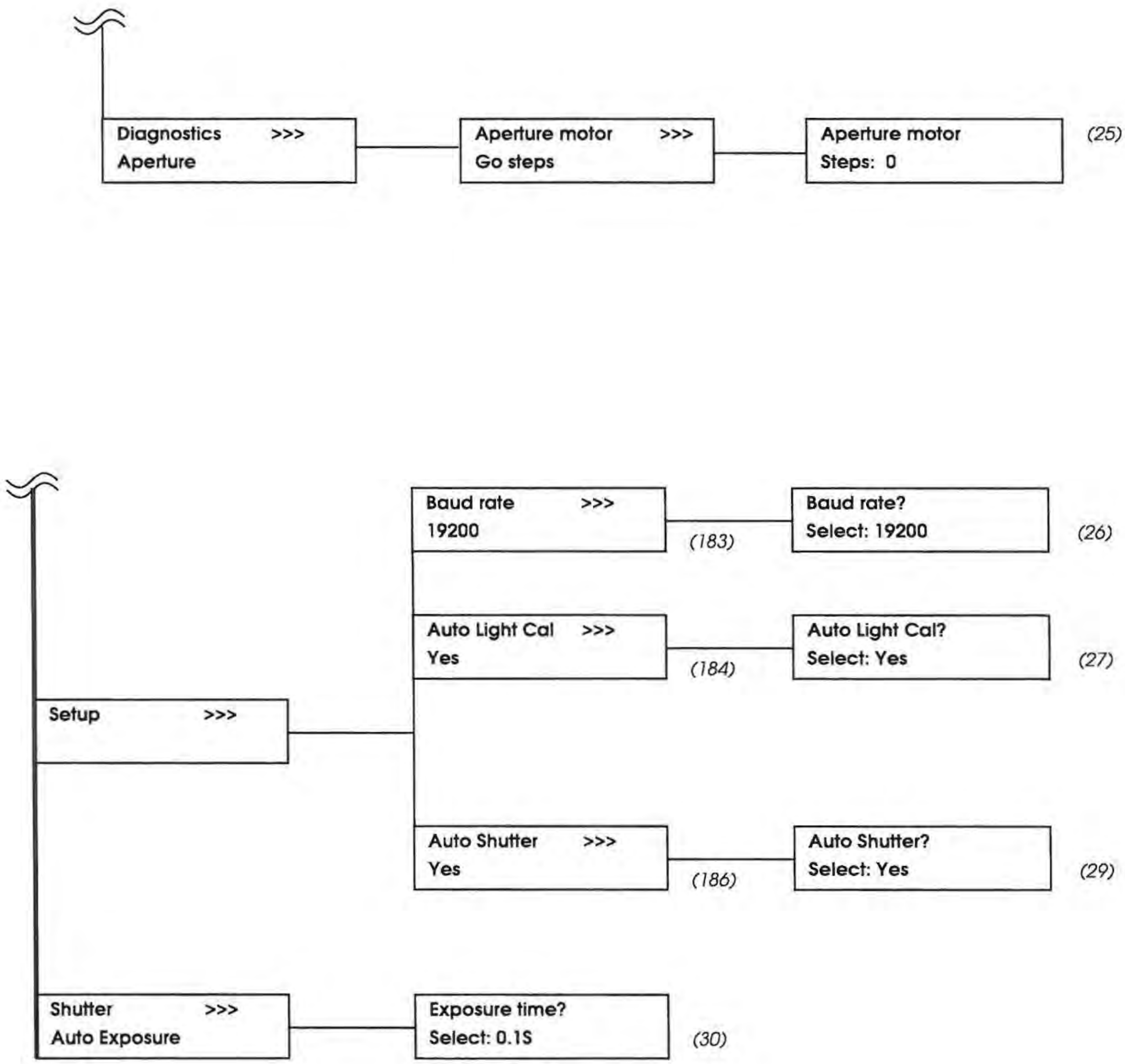

Figure 11-2b. Sabre Menu Tree, Extended Menus (Sheet 5 of 5)

Table 11-6. ASCII Table for RS-232 and IEEE 488 (1 of 2)

Hex	Oct	Dec	ASCII	IEEE Msg	Hex	Oct	Dec	ASCII	IEEE Msg
00	000	0	NUL		20	040	32	SP	MLA0
01	001	1	SOH	GTL	21	041	33	!	MLA1
02	002	2	STX		22	042	34	"	MLA2
03	003	3	ETX		23	043	35	#	MLA3
04	004	4	EOT	SDC	24	044	36	$	MLA4
05	005	5	ENQ	PPC	25	045	37	%	MLA5
06	006	6	ACK		26	046	38	&	MLA6
07	007	7	BEL		27	047	39	'	MLA7
08	010	8	BS	GET	28	050	40	(	MLA8
09	011	9	HT	TCT	29	051	41	)	MLA9
0A	012	10	LF		2A	052	42	*	MLA10
0B	013	11	VT		2B	053	43	+	MLA11
0C	014	12	FF		2C	054	44	,	MLA12
0D	015	13	CR		2D	055	45	-	MLA13
0E	016	14	SO		2E	056	46	.	MLA14
0F	017	15	SI		2F	057	47	/	MLA15
10	020	16	DLE		30	060	48	0	MLA16
11	021	17	DC1	LLO	31	061	49	1	MLA17
12	022	18	DC2		32	062	50	2	MLA18
13	023	19	DC3		33	063	51	3	MLA19
14	024	20	DC4	DCL	34	064	52	4	MLA20
15	025	21	NAK	PPU	35	065	53	5	MLA21
16	026	22	SYN		36	066	54	6	MLA22
17	027	23	ETB		37	067	55	7	MLA23
18	030	24	CAN	SPE	38	070	56	8	MLA24
19	031	25	EM	SPD	39	071	57	9	MLA25
1A	032	26	SUB		3A	072	58	:	MLA26
1B	033	27	ESC		3B	073	59	;	MLA27
1C	034	28	FS		3C	074	60	<	MLA28
1D	035	29	GS		3D	075	61	=	MLA29
1E	036	30	RS		3E	076	62	>	MLA30
1F	037	31	US		3F	077	63	?	UNL

Table 11-6. ASCII Table for RS-232 and IEEE 488 (2 of 2)

Hex	Oct	Dec	ASCII	IEEE Msg	Hex	Oct	Dec	ASCII	IEEE Msg
40	100	64	@	MTA0	60	140	96	`	MSA0,PPE
41	101	65	A	MTA1	61	141	97	a	MSA1,PPE
42	102	66	B	MTA2	62	142	98	b	MSA2,PPE
43	103	67	C	MTA3	63	143	99	c	MSA3,PPE
44	104	68	D	MTA4	64	144	100	d	MSA4,PPE
45	105	69	E	MTA5	65	145	101	e	MSA5,PPE
46	106	70	F	MTA6	66	146	102	f	MSA6,PPE
47	107	71	G	MTA7	67	147	103	g	MSA7,PPE
48	110	72	H	MTA8	68	150	104	h	MSA8,PPE
49	111	73	I	MTA9	69	151	105	i	MSA9,PPE
4A	112	74	J	MTA10	6A	152	106	j	MSA10,PPE
4B	113	75	K	MTA11	6B	153	107	k	MSA11,PPE
4C	114	76	L	MTA12	6C	154	108	l	MSA12,PPE
4D	115	77	M	MTA13	6D	155	109	m	MSA13,PPE
4E	116	78	N	MTA14	6E	156	110	n	MSA14,PPE
4F	117	79	O	MTA15	6F	157	111	o	MSA15,PPE
50	120	80	P	MTA16	70	160	112	p	MSA16,PPE
51	121	81	Q	MTA17	71	161	113	q	MSA17,PPE
52	122	82	R	MTA18	72	162	114	r	MSA18,PPE
53	123	83	S	MTA19	73	163	115	s	MSA19,PPE
54	124	84	T	MTA20	74	164	116	t	MSA20,PPE
55	125	85	U	MTA21	75	165	117	u	MSA21,PPE
56	126	86	V	MTA22	76	166	118	v	MSA22,PPE
57	127	87	W	MTA23	77	167	119	w	MSA23,PPE
58	130	88	X	MTA24	78	170	120	x	MSA24,PPE
59	131	89	Y	MTA25	79	171	121	y	MSA25,PPE
5A	132	90	Z	MTA26	7A	172	122	z	MSA26,PPE
5B	133	91	[	MTA27	7B	173	123	{	MSA27,PPE
5C	134	92	\	MTA28	7C	174	124			MSA28,PPE
5D	135	93	]	MTA29	7D	175	125	}	MSA29,PPE
5E	136	94	^	MTA30	7E	176	126	~	MSA30,PPE
5F	137	95	_	MTA31	7F	177	127	DEL	

OPERATOR'S MANUAL

APPENDIX A
PARTS LIST

COHERENT

Contact Coherent Customer Service for spare or replacement parts or for additional optics.

Table A-1 Argon Wavelength Selection and Optic Sets

Optic Set	Optic Set Bandwidth	Multiline Wavelength	Single Line Holder	HR	OC	Radius of OC
1	275.4 nm only [2]	275.4 nm	—	0160-493-00	0166-852-00	12 m
2	275.4 - 305.5 nm	MLDUV	D/SUV prism	0160-495-00	0166-853-00	12 m
3	300.3 - 335.8 nm	MLSUV	D/SUV prism	0161-015-00	0166-854-00	12 m
4	333.6 - 363.8 nm	MLUV	UV prism	0903-016-00	0166-855-00	12 m
5	351.1 - 385.8 nm	MLLUV	UV prism	0161-255-00	0166-856-00	12 m
6	454.5 nm only [3]	—	VIS prism	0903-004-00	0166-859-00	15 m
7	454.5 - 514.5 nm	MLVIS	VIS prism	0903-004-00	0166-858-00 or 0166-857-00 [4]	15 m
8	528.7 nm only [3]	—	VIS prism	0903-004-00	0166-860-00	10 m

[1] Single line selection is standard or available as an option dependent on optic set and system type.
[2] Requires Multiline Holder.
[3] Requires VIS Single Line Holder.
[4] Install 0166-857-00 to attain specified single line output powers of the 457.9 nm and/or Blue/Green options. Install 0166-858-00 for multiline configuration.

Table A-2. Krypton Wavelength Selection and Optic Sets

Optic Set	Optic Set Bandwidth	Multiline Wavelength	Single Line Holder	HR	OC	Radius of OC
1	337.5 - 356.4 nm [2]	MLUV	UV prism	0903-016-00	0903-061-00	15 m
2	406.7 - 415.4 nm [2]	MLVI	VIS/IR prism	0903-062-00	0160-013-00	10 m
3	468.0 - 530.9 nm [2]	MLBG	VIS/IR prism	0903-004-00	0155-264-00 or 0161-441-00 [3]	15 m
4	520.8 - 568.2 nm	MLYG	VIS/IR prism	0903-066-00 [4]	0903-067-00 [4]	15 m
5	647.1 - 676.4 nm	MLRED	VIS/IR prism	0903-068-00	0903-070-00	10 m
6	752.5 - 799.3 nm	MLIR	VIS/IR prism	0903-064-00	0903-065-00	10 m[5]

[1] Single line selection is standard or available as an option dependent on optic set and system type.
[2] Wavelengths ≤ 468.0 nm require magnet to be set to high field.
[3] Install 0161-441-00 to attain specified single line output powers of the 468.0, 476.2, and/or 482.5 nm options. Install 0155-264-00 for multiline configuration.
[4] Install Optic Set 4 to attain specified single line output powers of the 520.8, 530.9, and/or 568.2 nm options.
[5] Radius of HR also is 10 m.

Table A-3. Dominant Argon Single Lines

ARGON SINGLE LINES		
VIS Single Line Holder Wavelength (nm)	**UV Single Line Holder Wavelength (nm)**	**D/SUV Single Line Holder Wavelength (nm)**
528.7	385.8	335.8
514.5	379.5	334.5
501.7	363.8	333.6
496.5	351.1	305.5
488.0	335.8	302.4
476.5	334.5	300.3
472.7	333.6	275.4
465.8		
457.9		
454.5		

Table A-4. Dominant Krypton Single Lines

KRYPTON SINGLE LINES	
VIS/IR Single Line Holder Wavelength (nm)	**UV Single Line Holder Wavelength (nm)**
799.3	356.4
752.5	350.7
676.4	337.5
647.1	
568.2	
530.9	
520.8	
482.5	
476.2	
468.0	
415.4	
413.1	
406.7	

Table A-5. Etalon Optic

GAS TYPE	WAVELENGTHS	OPTIC THICKNESS	COATED/ UNCOATED	OPTIC PART #	OPTION ORDER #
Argon	333.6 - 385.8 nm	7.95 mm (0.313 in.)	Uncoated	0167-399-02	0166-498-01
Argon	454.5 - 514.5 nm	10.16 mm (0.400 in.)	Coated	0502-908-01	0166-498-00
Argon	528.7 nm	10.16 mm (0.400 in.)	Uncoated	0502-908-02	0166-498-02
Krypton	337.5 - 482.5 nm	10.16 mm (0.400 in.)	Uncoated	0502-908-02	0166-498-02
Krypton	520.8 - 676.4 nm	10.16 mm (0.400 in.)	Coated	0502-908-01	0166-498-00

Table A-6. Miscellaneous Spare Parts

ITEM DESCRIPTION	COHERENT PART NO.
Fuse, 80 Amps	5110-0288
Spare Key	5107-0180
DI/DO Cartridge Assembly	0167-322-00
O-ring: Power supply to umbilical seal	2506-0017

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Appendix B
Aperture Sizes

COHERENT

Table B-1. Argon Automatic Aperture Sizes

APERTURE POSITION	DIAMETER (in.)
OPEN	0.234 ± 0.005
18	0.1263 ± 0.0005
17	0.1243 ± 0.0005
16	0.1223 ± 0.0005
15	0.1203 ± 0.0005
14	0.1183 ± 0.0005
13	0.1163 ± 0.0005
12	0.1143 ± 0.0005
11	0.1123 ± 0.0005
10	0.1103 ± 0.0005
9	0.1083 ± 0.0005
8	0.1063 ± 0.0005
7	0.1043 ± 0.0005
6	0.1023 ± 0.0005
5	0.1003 ± 0.0005
4	0.0983 ± 0.0005
3	0.0963 ± 0.0005
2	0.0943 ± 0.0005
1	0.0923 ± 0.0005
CLOSED	no hole

Table B-2. Krypton Automatic Aperture Sizes

APERTURE POSITION	DIAMETER (in.)
OPEN	0.234 ± 0.005
18	0.1373 ± 0.0005
17	0.1343 ± 0.0005
16	0.1313 ± 0.0005
15	0.1283 ± 0.0005
14	0.1253 ± 0.0005
13	0.1223 ± 0.0005
12	0.1193 ± 0.0005
11	0.1163 ± 0.0005
10	0.1133 ± 0.0005
9	0.1103 ± 0.0005
8	0.1083 ± 0.0005
7	0.1063 ± 0.0005
6	0.1043 ± 0.0005
5	0.1023 ± 0.0005
4	0.1003 ± 0.0005
3	0.0983 ± 0.0005
2	0.0963 ± 0.0005
1	0.0943 ± 0.0005
CLOSED	no hole

Operator's Manual

Appendix C
Warranty

COHERENT

Ion Laser Warranty

The terms and conditions listed below for ion laser systems cover the standard warranty and are applicable only to lasers purchased directly from Coherent and used for scientific purposes. Special terms and conditions apply to OEM and industrial markets. The standard warranty is included in prices listed for ion laser systems. If desired, the standard warranty can be modified to more exactly meet the needs of a particular customer. Contact our Santa Clara office for information on warranty modifications.

All laser parts replaced under warranty shall become the property of Coherent, Inc. and must be returned to Coherent, Inc., 5100 Patrick Henry Drive, Santa Clara, CA 95054, or to a facility designated by Coherent, Inc. All laser systems must be carefully packed in the shipping containers provided by Coherent, Inc. prior to returning them to the factory.

Attempting unauthorized repairs, performing unauthorized procedures, opening chassis covers, or other actions that are not described or supported in this manual will void the warranty.

INNOVA® Ion Laser Systems

INNOVA ion laser systems are warranted for parts and labor for a period of:

- INNOVA Enterprise—Twelve (12) months or 2000 hours
- INNOVA Models 310, 415, 420 and 425—Twenty-four (24) months or 3000 hours
- INNOVA Sabre—DBW: 18 (eighteen) months or 2000 hours. TSM: Twenty-four (24) months or 3000 hours
- All other INNOVA Models, except lasers sold for entertainment applications—Eighteen (18) months or 2000 hours

whichever occurs first, to conform to Coherent's published specifications and be free from defects in materials and workmanship. Travel time and travel costs for on-site service are included during the first ninety (90) days of the warranty period. For systems that do not include installation in the purchase price (code "C"), warranty begins from date of shipment. For systems that include installation (code "A"), warranty begins at date of installation or thirty (30) days from date of shipment, whichever occurs first. Laser sold for

entertainment applications are covered by a separate warranty; contact your Coherent representative for details.

IonPure™ Plasma Tubes

IonPure replacement plasma tubes are warranted for parts and labor for a period equal to that of the original standard warranty on the laser system (see above under "INNOVA Ion Laser Systems"). Travel time and travel costs for on-site service are included during the first ninety (90) days of the warranty period. Tube warranty begins from date of installation, or thirty (30) days from date of shipment, whichever occurs first.

Productivity Plus™ Service Agreements

Agreements are available to cover most Coherent INNOVA laser systems. Productivity Plus service agreement coverage includes labor, zone-travel charges, and replacement parts, including the tube, but does not include the BBO crystal for INNOVA 300 FReD™ laser systems. Coverage does not include consumable items. Productivity Plus agreements may be purchased at any time provided the system is currently under its original warranty or covered under an existing Productivity Plus agreement.

If a system is out of warranty, a service visit is required to ensure the system is up-to-date and meets all specifications. The customer will be charged for all travel, parts, and labor necessary to bring the system up-to-date and within specifications prior to the start of any service agreement. Contact your local Coherent Service Representative for information on service agreements.

Other Products

Other products not specifically listed above are warranted to: (a) conform to Coherent's published specifications and (b) be free from defects in materials and workmanship. This warranty covers parts and labor and is for a period of twelve (12) months from the date of shipment from F.O.B point.

Responsibilities of the Buyer

The buyer is responsible for providing appropriate utilities and an operating environment as outlined in the product literature and/or preinstallation manual. Damage to the laser systems caused by failure of buyer's utilities or failure to maintain an appropriate operating environment is solely the responsibility of the buyer and is specifically excluded from any warranty, warranty extension, or service agreement.

The buyer is responsible for prompt notification to Coherent of any claims made under warranty. In no event will Coherent be responsible for warranty claims made later than seven (7) days after the expiration of the warranty.

Limitations of Warranty

The foregoing warranty shall not apply to defects resulting from:

1. Components or accessories with separate warranties manufactured by companies, other than Coherent, which have separate warranties,
2. Improper or inadequate maintenance by the buyer,
3. Buyer-supplied interfacing,
4. Operation outside the environmental specifications of the product,
5. Improper site preparation and maintenance, or
6. Unauthorized modification or misuse.

Coherent assumes no responsibility for customer-supplied material. The obligations of Coherent are limited to repairing or replacing, without charge, equipment which proves to be defective during the warranty period. Replacement tubes may contain reconditioned parts. Repaired or replaced parts are warranted for the duration of the original warranty period only. Our warranty does not cover damages due to misuse, negligence or accidents, or damages due to installations, repairs or adjustments not specifically authorized in writing by Coherent.

Warranty applies only to the original purchaser at the initial installation point in the country of purchase, unless otherwise specified in the sales contract. Warranty is transferable to another location or to another customer only by special agreement which will include additional inspection or installation at the new site. Coherent disclaims any responsibility to provide product warranty, technical or service support to a customer that acquires products from someone other than Coherent or an authorized representative. This includes any third party tube refurbishment provided in order to upgrade or maintain the operation of the tube.

THIS WARRANTY IS EXCLUSIVE IN LIEU OF ALL OTHER WARRANTIES, WHETHER WRITTEN, ORAL, OR IMPLIED, AND DOES NOT COVER INCIDENTAL OR CONSEQUENTIAL LOSS. COHERENT SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF

MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

The terms and conditions set forth in any Coherent Order Acknowledgment shall govern over any conflicting terms set forth herein or in customer's purchase order.

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APPENDIX D ELECTROMAGNETIC COMPATIBILITY

COHERENT

This laser was designed to meet the European council directive for electromagnetic compatibility (EMC directive). It has been constructed so that:

(a) the electromagnetic disturbance it generates does not exceed a level allowing radio and telecommunications equipment to operate as intended;

(b) the laser has an adequate level of intrinsic immunity of electromagnetic disturbance to enable it to operate as intended.

Emissions

The laser meets the emission requirements of Class A, group 1 as specified in the European harmonized standard EN55011 (1991), 'Limits and methods of measurement of radio disturbance characteristics of industrial, scientific and medical (ISM) radio-frequency equipment.'

Consult your competent national authorities if the installation site requires the laser to meet Class B requirements. Although Class A limits have been derived for industrial and commercial establishments, administrations may allow, with whatever additional measures are necessary, the installation and use of Class A ISM equipment in a domestic establishment or in an establishment connected directly to domestic electricity power supplies.

Immunity

The laser meets the immunity requirements of the European harmonized standard EN50082-1 (1992), 'Electromagnetic compatibility- Generic immunity standard Part 1: Residential, commercial and light industry.'

The laser in particular, meets the requirements for immunity to

- electrostatic discharge, level x, 8 kV Air (IEC 801-2),
- radiated electromagnetic fields, level 2, (IEC 801-3),
- electrical fast transients/bursts, level 2 (IEC 801-4),
- power surges, level 2 (IEC 801-5).

Additional measures might be required for installations where more severe levels of electromagnetic disturbances are encountered. Examples of such measures are routing of laser system cables separate from other power cables, ESD

prevention equipment for the operator, additional surge protector or additional shielding depending on the kind of electromagnetic disturbance.

The performance criteria for the laser during these immunity tests was stable output power. This was verified by measurement of the laser beam power during the tests with a laser power meter. A beam power variation of less than ±5% is deemed acceptable performance in the presence of electromagnetic disturbances. The laser did not change its operating mode or lose any stored data during the tests. Other laser specifications were not verified or monitored during these tests.

Operator's Manual

Glossary

Coherent

Glossary

°C	Degrees centigrade or Celsius
°F	Degrees Fahrenheit
λ	Lambda (wavelength symbol)
$1/e^2$	Beam diameter parameter = 0.13534
Ω	Ohms (resistance)
Amp	Amperes
AC	Alternating current
ADC	Analog-to-digital converter
Ar	UHP argon (lasing medium)
Ar^+	Ionized argon
BTU	British thermal unit
CDRH	Center for Devices and Radiological Health (U.S. Government)
CFR	Code of Federal Regulation
cm	Centimeters = 10^{-2} meters
CPU	Central processing unit
CW	Continuous wave (operating mode)
DAC	Digital- to-analog converter
DC	Direct current
DI/DO	De-ionizing and de-oxygenating
D/SUV	Deep/Short Ultraviolet (wavelengths)
DVM	Digital voltmeter
FWHM	Full width at half of maximum
GHz	GigaHertz = 10^9 Hertz
Hz	Hertz or cycles per second (frequency)
IR	Infrared (wavelength)
kΩ	Kilohms
kΩ-cm	Kilohm-centimeter (resistivity)
kg	Kilograms
Kr	UPH krypton (lasing medium)
Kr^+	Ionized krypton
kV	Kilovolts = 10^3 volts
kW	Kilowatts = 10^3 watts
l	Liters (volume)
lbs	Pounds
LC	Inductance/capacitance (electronic filter)
LCD	Liquid crystal display
LED	Light emitting diode
m	Meters (length)
mA	Milliamps

Glossary (Continued)

mg	Milligrams = 10^{-3} grams
MHz	Megahertz = 10^{6} Hz
MLBG	Multiline Blue/green
MLDUV	Multiline Deep Ultraviolet
MLIR	Multiline Infrared
MLLUV	Multiline Long Ultraviolet
MLRED	Multiline Red
MLSUV	Multiline Short Ultraviolet
MLUV	Multiline Ultraviolet
MLVI	Multiline Violet
MLVIS	Multiline Visible
MLYG	Multiline Yellow/green
mm	Millimeters = 10^{-3} Meters
mrad	Milliradians = 10^{-3} Radians (Angle)
MΩ	Megohms = 10^{6} Ohms (Resistance)
mW	Milliwatts = 10^{-3} Watts (Power)
nm	Nanometers = 10^{-9} meters (wavelength)
psi	Pounds per square inch
psig	Pounds per square inch gauge
RAM	Random access memory
RMS	Root mean square (effective value of a sinusoidal wave)
SCFH	Cubic feet per hour at a standard flow temperature and pressure
TEM	Transverse electromagnetic (cross-sectional laser beam mode)
TTL	Transistor-to-transistor logic
UHP	Ultra high purity
UV	Ultraviolet (wavelengths)
V	Volts
VAC	Volts alternating current
VDC	Volts direct current
V/I	Voltage/current
VIS	Visible (wavelengths)
VIS/IR	Visible/Infrared (wavelengths)
W	Watts (power)

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Coherent Part Number: 0167-697-00, Rev C

SABRE™

ION LASER

UPPER MENU LEVELS

DEFAULT MENU

- Laser Off / Turn On: 50.1A
- Start Delay: 25 / Turn On: 50.1A — select / exit
- 50.1A 7.45W CUR / 514.5nm TEM00 PTon

Upper menu levels (each with select / exit):

- Status: Argon >>> / Software: 1.0
- Aperture >>> / TEM00 AP#9
- Wavelength >>> / 514.5nm
- Etalon: NuTrack >>> / T=52.706 ZDAC=2132
- Memory >>> / Programming
- Magnet >>> / Low Field

Standard ↑ / ↓ Extended

- Diagnostics >>>
- Setup >>>
- Shutter >>> / Auto Exposure

DIAGNOSTIC MENU (CONT.)

Diagnostics >>> / Light Regulation — select / exit

- Photocell Inputs / 1=555 2=276 3=567
- Photocell Temp / 51.5 °C
- PC Monitor Flag >>> / 1 — select / exit → PC Monitor Flag? / Select: 0 (△ ▽ select / exit)
- Photocell Gain >>> / 2 — select / exit → Photocell Gain? / Select 2 (△ ▽ select / exit)
- Light Reg Errors / 00000000
- Light Reg Setpoint / 0xb1a
- Light Reg Gain / 0xff

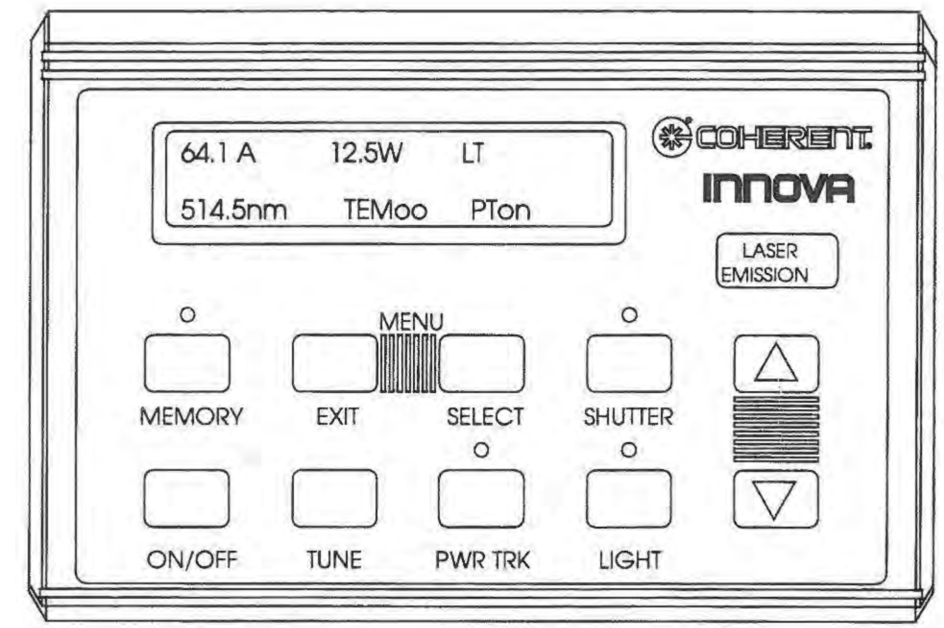
Diagnostics >>> / Rear Mirror — select / exit

- Horizontal motor >>> / Go steps — select / exit → Horizontal motor / Steps: 0 (△ ▽ select / exit)
- Vertical motor >>> / Go steps — select / exit → Vertical motor / Steps: 0 (△ ▽ select / exit)
- Goto cal position >>> — select / exit → Multiline position / Press Select (△ ▽ select / exit)
- Search rear plate >>> — select / exit → Search rear plate / Press Select (select / exit)

Diagnostics >>> / Aperture — select / exit

- Aperture motor >>> / Go steps — select / exit → Aperture motor / Steps: 0 (△ ▽ select / exit)

The remote is capable of displaying a standard set and an extended set of menus. Set switch 8 on the MY TALK ADDRESS DIP switch on the rear panel of the Sabre power supply to the up (ON) position to access the extended set.



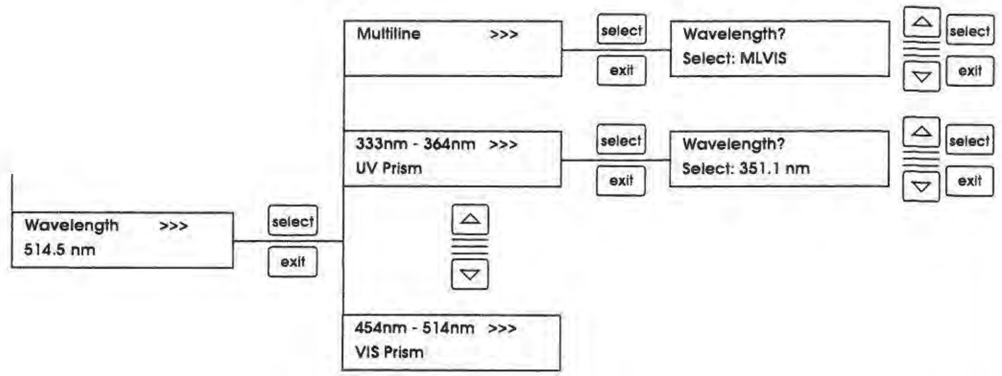
INNOVA® TECHNOLOGY

Sabre Remote Control Menu Quick Reference Card

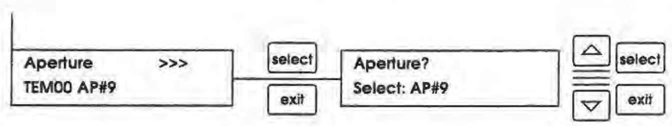
Coherent P/N: 0167-835-00, Rev B

COHERENT
Coherent Laser Group
5100 Patrick Henry Drive
Santa Clara, CA 95054

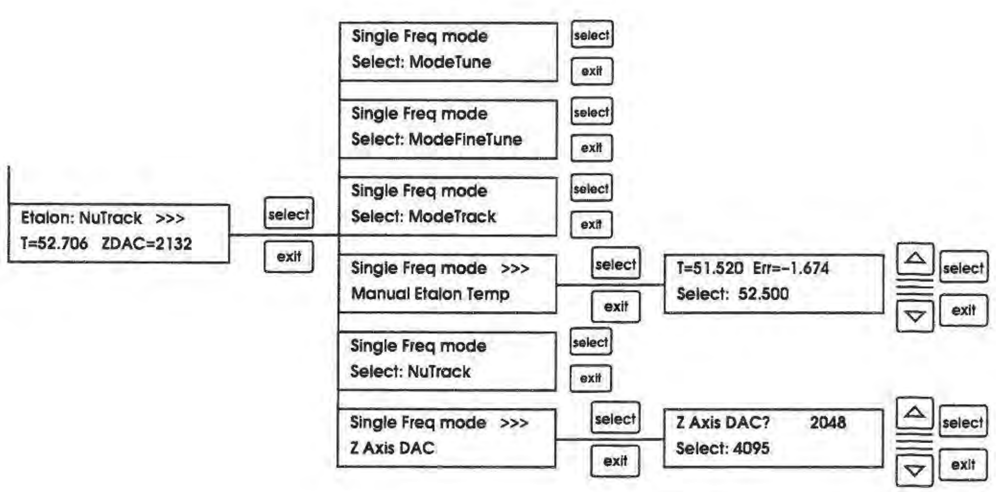
WAVELENGTH MENU



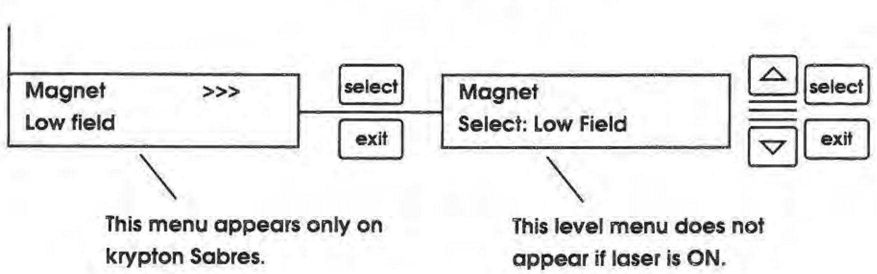
APERTURE MENU



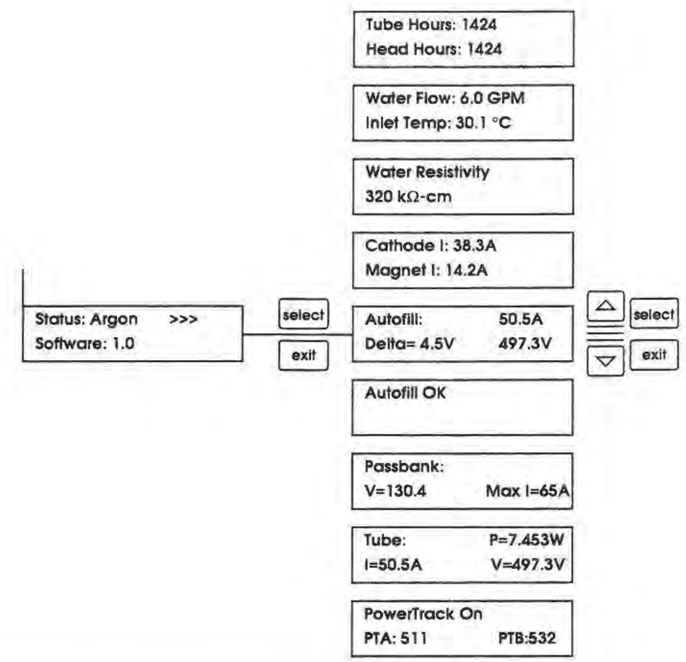
ETALON MENU



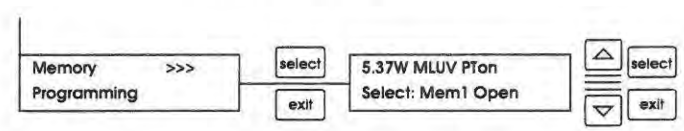
MAGNET MENU



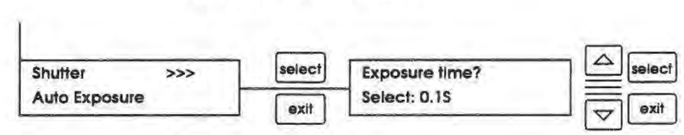
STATUS MENU



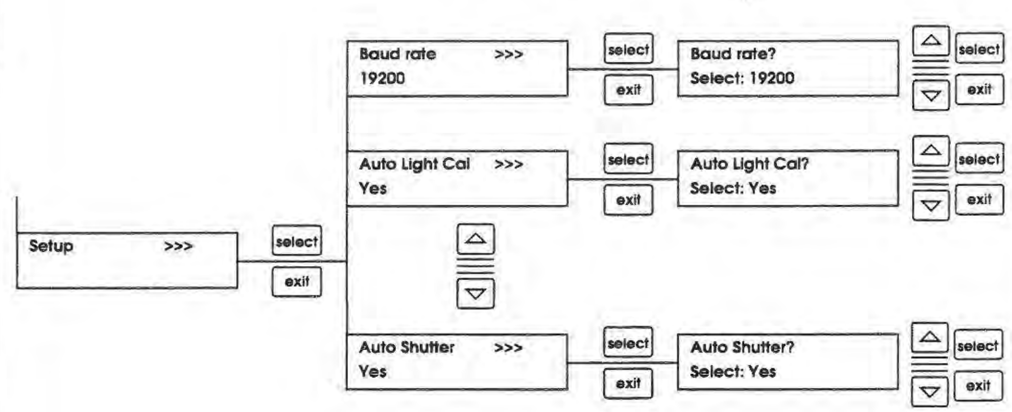
MEMORY MENU



SHUTTER MENU



SETUP MENU



DIAGNOSTIC MENU